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DDT and Its Metabolites in Mexico

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1. Introduction

DDT (dichlorodiphenyltrichloroethane) was first synthesized in 1874, and its insecticidal properties were discovered in 1939 by Paul Hermann Müller (Stapleton 1998). The U.S. military began using DDT extensively for mosquito control in 1944, particularly in the Pacific, where much of the action of World War II took place in highly malarious areas (Stapleton 1998). In 1955, the World Health Organization (WHO) started a global malaria control program with DDT; by 1958, 75 countries had joined and, at the peak of the campaign, 69,500 tons of pesticides mainly DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane] were applied to 100 million dwellings each year (Wijeyaratne, 1993). For the control of malaria, houses were sprayed twice a year with DDT wettable powder to kill resting mature Anopheles mosquito. Later, the Stockholm Convention on Persistent Organic Pollutants, which came into force on 17 May 2004, outlawed the use of 12 chemicals including DDT (UNEP, 2004). However, one exemption clause allows malaria-endemic nations to use DDT, strictly for disease vector control. The United Nations Environment Program estimates that about 25 countries will use DDT under exemptions from the DDT pesticide ban (POPs, 2009). Thus, in regard to presence of DDT around the world can be divided into three scenarios: Sites where DDT is still in use; sites where the presence is due to DDT sprayed several years ago, and sites where the presence of DDT is the result of a long-range transport of the insecticide to areas where it was never used like the Antarctic. In Mesoamerica (Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama) DDT was used until the year 2000, Mexico and Nicaragua being the last nations that applied the insecticide in agriculture and for the control of malaria. Table 1 lists the period and the total amount of DDT used in each Mesoamerican country by the malaria control programs. The amount used (approximately 85,000 tons between 1946 and 1999) together with the high environmental persistence of DDT and its metabolites, provide the necessary conditions for DDT to become a contaminant of concern for this region of the world (ISAT, 2002). Taking into account the environmental persistence and the toxicity of DDT, a program for the control of malaria without using insecticides in Mesoamerica was developed between 2004 and 2007, with assistance from the Pan American Health Organization [PAHO; (Chanon et al., 2003; PAHO, 2008)]. The phase-out of DDT in Costa

Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua and Panama was part of a regional proposal supported by the Global Environment Facility (GEF) and the United Nations Environmental Program with the participation of the North American Commission for Environmental Cooperation (CEC).

2. DDT in Mexico

In 1944, and for the first time, houses were sprayed with DDT in Temixco, Morelos, Mexico (Stapleton 1998). The spray was applied to the walls and ceilings of residences. Studies done two months after the spraying, showed that there was a 99% reduction in the incidence of Anopheles (Stapleton 1998). In 1947–48, the spraying of DDT began in other Mexican regions, such as Veracruz, Mexico City and Baja California (Stapleton 1998). By 1948, the first clear evidence of malaria control appeared in the areas first sprayed with DDT; the overall parasite rate in the state of Morelos was found to be 10%, and the rate in the sprayed towns was found to be 1% (Stapleton 1998). In 1936 it was estimated that half of the Mexican population lived in endemic regions and was subject to a malaria mortality rate of 0.5%, or about 36,000 deaths per year (Stapleton 1998).During the 1930s and 1940s, malaria became the third cause of death in the country. However, the antimalaria campaign was not generalized until 1956 (CCE 1998). The success of DDT was outstanding, malaria cases decreased from 41,000 in 1955 to 4,000 in 1960 (Fernández de Castro 1998); in 1970 the campaign was relaxed and the cases increased to 57,000 (Fernández de Castro 1998). However, this was also the time in which DDT production peaked in Mexico, with more than 80 thousand tonnes produced annually (CCE 1998). In recent years, the incidences of malaria have declined significantly, to less than 5,000 cases. Since 1982 there have been no deaths from this disease. As, showed, Malaria is a long-standing public health problem that has inhibited development in large areas of the country. Approximately 60% of the Mexican territory, representing an area inhabited by close to 45 million people, provides an environment suitable for malaria transmission. This includes the Pacific coast, the Gulf of Mexico slopes, the Yucatan peninsula and interior basins of the high plateau. (CCE 1998). In actuality, Mexico operates a malaria control program that has substantially reduced the incidence of this disease. In 1995, Mexico initiated an integrated pest management approach for malaria to reduce the heavy dependence on pesticides. Much of the success of Mexico's malaria control program (there have been no recorded deaths from malaria since 1982) is due to improvements in sanitation, increased disease surveillance, and integrated pest management schemes that focus pesticide applications on critical habitats and stages in the mosquito's life cycle (Government of Mexico 1998). Since 1998, DDT was substituted with pyrethroids in the malaria control program. In other hand, In the area of agriculture, as much as 1,000 tonnes per year were used (CCE 1998).Application rates in the north of Mexico, were among the highest in the world (CCE 1998). However, the growing concern about DDT persistence has had a significant impact on agricultural practices in Mexico. During the early 1970s the US Food and Drug Administration (USFDA) began rejecting the importation of commodities due to high residue levels, especially of DDT (CCE 1998). Therefore, some agricultural areas changed to newer pesticides in order to comply with the USFDA regulations. By 1990, DDT was limited to campaigns addressing public sanitation (CCE 1998). In recognition of DDT's environmental and human health effects, Mexico shifted the emphasis of its anti-malarial campaigns away from DDT beginning in

the 1980s and 1990s, and the use of the pesticide was gradually reduced. In 1997, the Intergovernmental Forum on Chemical Safety agreed there was sufficient evidence to take international action to restrict and reduce the use of DDT.

Country	Period of use	Total tons
México	1957-2000	69,545.00
Nicaragua	1959-1991	2,172.00
Costa Rica	1957-1985	1,387.00
Guatemala	1958-1979	4,790.00
Honduras	1950-1978	2,640.00
El Salvador	1946-1973	4,271.00
Panamá	1967-1971	189.00

Table 1. History of DDT use in Mesoamerica countries (ISAT, 2002).

3. Environmental pathways of exposure to DDT

The physicochemical properties of DDTs (Table 2) show the extent of their volatility and the high KOW/KOA value shows that they are more likely to partition into environmental sectors which exhibit greater organic phases (biota, soil, and sediment). The concentration of DDTs in the water samples may be limited due to characteristically low water solubility. In other hand, the exposure pathways are the processes by which DDT may be transported from the pollution source to living organisms. In the malaria areas, the source of DDT was the household-spraying of the insecticide. Since the beginning of the control program of malaria, DDT was sprayed on the ceilings and walls, both indoors and outdoors. Therefore, after spraying, indoor dust (or indoor soil in some cases), and the external surface soil in those areas next to the dwellings, were the media first to become contaminated with DDT. From these points, the insecticide could be transported from one medium to another by different processes.

Compound	Molecular weight	Vapor pressure (Pa)	Aqueous solubility (mol/m^3)	Henry´s law constant (Pa m^3/mol)	Log Kow*	Log Koa
p´p-DDT	354.5	0.00048	0.00042	1.1	6.39	9.73
p´p-DDE	319.0	0.00340	0.00079	4.2	6.93	9.70
p´p-DDD	321.0	0.00120	0.00230	0.5	6.33	10.03

Table 2. Physicochemical properties of DDT and its metabolites at 25^0 C. (Sahsuvar et al. 2003; Shen and Wania 2005).

Soil and Dust

Several studies have identified indoor house dust as an important pathway of toxicant exposure. Often levels of pollutants found in house dust, including compounds banned long ago such as DDT, are significant sources of exposure for the general population, especially children (Butte and Heinzow 2002; Hwang et al. 2008; Rudel et al. 2003). Moreover, analyses of compounds in house dust are a measure of indoor contamination, but may also provide valuable information on the assessment of human indoor exposure (Butte and Heinzow 2002). Also, outdoor soil is considered an important exposure pathway for the general population and children to compounds banned long ago (Herrera-Portugal et al. 2005). However, it is important to note that longer residence times and elevated contaminant concentrations in the indoor environment may increase the chance of exposure to these contaminants by 1,000-fold compared to outdoor exposure (Hwang et al. 2008).

Tables 3 and 4 show DDT levels in outdoor and indoor surface soils, respectively. Taking into account the guideline for DDT in residential soil: 0.7 mg/kg from Canada (Environment Canada, 2007) different scenarios have been observed in Mexico. Regarding outdoor levels, in general lower levels were found in household outdoor samples (Table 3). With exception of levels found in Chiapas and Oaxaca, that have levels lower than Canadian guide (Table 3). In other hand, high levels are recorded in indoor levels in different regions of Mexico, generally higher than Canadian guideline (Table 4). Also, we can note that the higher levels of DDT in those environment media were found in indoor dust samples, generally with levels above the Canadian guideline (Table 5). Moreover, the data in Tables 3, 4 and 5 indicate high levels of total DDT in soil and dust in all regions studied in Mexico when compared with studies around the world.

Water

DDT, DDD and DDE (DDTs) are only slightly soluble in water, with solubilities of 3.4 ppb, 160 ppb and 120 ppb, respectively (ATSDR 2010). In this regard, sedimentation is the most important factor for the disappearance of DDT from water. However, it has also been suggested that contaminated sediments are a main source of DDT inputs to the water column (Zeng 1999). In order to study the degree of pollution in water bodies

located in tropical areas, DDTs were quantified in a relatively small stream. The levels of total DDT found in the tropical area was 280 pg/L (Carvalho et al. 2009). In other hand, levels of total DDT found in the tropical area in United states of America was 10300 pg/L (California 1999)

Sediments

As stated above, sediments act as the primary reservoir for excess quantities of DDT. Therefore, it is very important to analyze the concentrations in this medium. In Table 6 it is shown that DDT concentrations in Mexican samples are lower than those detected in other countries, where DDT was used either for the control of malaria or for agricultural practices. Whether this difference can be explained by an increased degradation or by a DDT mass reduction caused by water currents carrying suspended DDTs out of the contaminated area, are issues that deserve further research. However, we cannot exclude another explanation. The Mexican studies, results of which are shown in Table 6, were not designed to assess the amount of DDT in sediments due to spraying. In fact, a sediment sample collected in a river near an area where the insecticide was used intensively for vector control, had DDT concentrations of up to 70.0 mg/kg (Gonzalez-Mille et al. 2010). Discvutir disminución.

Location	Total DDT (mg/Kg)	Region	Reference
Chiapas	0.95	Southeastern	Martínez-Salinas et al. 2011
Chiapas	8.20	Southeastern	Yañez et al. 2002
Oaxaca	0.90	Southeastern	Yañez et al. 2002
Tabasco	0.04	Southeastern	Torres-Dosal et al. 2011
Chihuahua	0.45	North	Díaz-Barriga et al. 2011
Veracruz	0.01	Southeastern	Espinosa-Reyes et al. 2010
Puebla and Mexico	0.07	Central	Waliszewski et al. 2008

Table 3. Total DDT levels in outdoor surface soil (mg/Kg) in different Mexican Regions.

Mexican state	Total DDT (mg/Kg)	Region	Reference
Chiapas	6.8	Southeastern	Martínez-Salinas et al. 2011
Chiapas	7.1	Southeastern	Yañez et al. 2002
Oaxaca	0.15	Southeastern	Yañez et al. 2002
Chihuahua	0.95	North	Díaz-Barriga et al. 2011

Table 4. Total DDT levels in indoor soil (mg/Kg) in different Mexican Regions.

Food and Biota

Due to their lipophilic attributes and high persistence, the DDTs may bioaccumulate significantly in animal species (Fisher 1995). Furthermore, biomagnification has been observed; for example, DDT concentration increased with each successive trophic level in a food chain (Fisher 1995).Taking into account these properties, food ingestion can be considered a pathway of exposure. In Mexico, studies have been done in different food items, such as fish, hen's egg, butter and cow's milk and muscle. In Table 7, total DDT levels in different food items are presented. Considering fish, the concentrations of DDT, in organisms collected in Mexico, are above normal values. As is shown in Table 8, where DDTs levels in Fish are depicted for different countries. We can note that the food item with high levels of DDT are food rich in fat as butter and cow´s milk (Table 7).

Location	Total DDT (mg/Kg)	Region	Reference
Chiapas	6.9	Southeastern	Martínez-Salinas et al. 2011
Chihuahua	1.0	North	Díaz-Barriga et al. 2011

Table 5. Total DDT levels in dust (mg/Kg) in different Mexican Regions.

Location	Total DDT (μg/Kg)	Region	Reference
Estado, Mexico (bay)	1.5	Southeastern	Noreña-Barroso et al. 1998
Mexico (bay)	0.6	Southeastern	Noreña-Barroso et al. 2007
Mexico (river)	74.0	Southeastern	Gonzalez-Mille et al. 2010
Mexico (lagoon)	4.9	Southeastern	Botello et al. 2000
China (Bay)	7.8		Liu et al. 2011
China (river)	3.8		Tan et al. 2009
Korea (bay)	3.4		Khim et al. 2001
Japan (bay)	1.2		Kim et al. 2007

Table 6. Total DDT levels in sediment (mg/Kg) in different Mexican Regions.

Air

Because DDTs have a Henry's Law constant value of 10–4/10–5 atm m3 mol, they are considered moderate volatile compounds [5]. Therefore, these compounds can be transported by air, either in the gaseous phase or adsorbed to atmospheric particles [5].Photodegradation of DDT occurs slowly; thus, residues of these pesticides are ubiquitous in the atmosphere, although at lower concentrations. Information on the atmospheric levels of OCs in Mexico is scarce. Previous studies in southern Mexico found that DDT and toxaphene concentrations in air were 1-2 orders of magnitude above levels in the Laurentian Great Lakes and arctic regions (24-26). Atmospheric levels in southern Mexico were generally higher than those in central Mexico (27), Costa Rica (28, 29) and Cuba (30), and comparable to those in Belize (31).

Recently, two important studies regarding DDT and its metabolites in air has been developed. Passive air samplers (PAS) were deployed at four sampling sites at the southern Mexico in 2002-2004 and eleven sampling sites across Mexico during 2005-2006 (referencia). The total DDT levels ranged from 239 to 2360 pg/m^3 in 2002-2004 (referencia) and from 15 to 1975 pg/m^3 in 2005-2006 (refernecia). Table ? shows the Total DDT air levels in the sampling sites in both studies. Total DDT tended to be higher in the south (poner siglas) and

some central sites (sigles). While, the other central and northern sites had lower total DDT levels (poner siglas). It is important to note that the higher levels were found in tropical sites where DDT was used for health campagnes or for agriculture as MT, CEL and VC (Table ?).

Location	Food	Total DDT (mg/Kg)	Region	Reference
Mexico country	Butter	88.0		Waliszewski et al. 2003
Veracruz	Cow´s milk	39.0	Southeastern	Pardio et al. 2003
Campeche	Oysters	5.9	Southeastern	Carvalho et al. 2009
Campeche	Oysters	1.5	Southeastern	Gold-Bouchot et al. 1995
Tabasco	Oysters	6.2	Southeastern	Botello et al. 1994
Campeche	Shrimps	0.25	Southeastern	Gold-Bouchot et al. 1995
Campeche	Mussels	1.44	Southeastern	Gold-Bouchot et al. 1995
Baja California	Mussels	9.16	North	Gutierrez-Galindo et al. 1988

Table 7. Total DDT levels in food items (mg/Kg) in different Mexican Regions.

Location	Total DDT (ng/g lipid)	Region	Reference
Veracruz, Mexico	25.0	Southeastern	Gonzalez-Mille et al. 2010
Chiapas, Mexico	4.7	Southeastern	Pérez-Maldonado et al. 2010
Hidalgo, Mexico	7.3	Central	Fernandez-Bringas et al. 2008
Costa Rica	0.6		Pérez-Maldonado et al. 2010
Honduras	< LOD (below detection limit)		Pérez-Maldonado et al. 2010
Nicaragua	3.9		Pérez-Maldonado et al. 2010
El Salvador	3.8		Pérez-Maldonado et al. 2010
Guatemala	< LOD		Pérez-Maldonado et al. 2010

Table 8. Total DDT levels in fish (mg/Kg) in different Mexican Regions.

Community	Total DDT (pg/m3)	Region	Reference
Baja California	338	North	Wong et al. 2009
Chihuahua	34	North	Wong et al. 2009
Yucatan	1975	Southeastern	Wong et al. 2009
Colima	750	North	Wong et al. 2009
Veracruz	129	Southeastern	Wong et al. 2009

Community	Total DDT (pg/m3)	Region	Reference
Morelos	500	Central	Wong et al. 2009
Sinaloa	76	North	Wong et al. 2009
Mexico DF	55	Central	Wong et al. 2009
Nuevo Leon	15	North	Wong et al. 2009
San Luis Potosi	21	Central	Wong et al. 2009
Veracruz	50	Southeastern	Wong et al. 2009
Tabasco	239	Southeastern	Alegría et al. 2008
Chiapas	2360	Southeastern	Alegría et al. 2008
Chiapas	547	Southeastern	Alegría et al. 2008
Veracruz	1200	Southeastern	Alegría et al. 2008

Table 9. Total DDT levels in air (pg/m3) in different Mexican Regions.

4. Human exposure to DDT

Biomonitoring studies are a useful instrument in formulating environmental health policies. For example, in Mexico during the last decade, studies in children led to the reduction or elimination of different chemicals such as lead, lindane and inclusive DDT. Furthermore, the biomonitoring of susceptible populations is a valuable method for the identification of critical contaminants, as has been shown in the United States with the National Health and Nutritional Examination Survey (NHANES III; Needham et al., 2005). Information about human exposure to chemicals is very limited; besides, in relation to children, the information is even more scarce. In this regard, in this text, we shall present data for breast milk, blood serum and adipose tisssue. Results have been done in adults and children.

In other hand, a biomarker of exposure is a xenobiotic substance or its metabolite (s), that is measured within a compartment of an organism. The preferred biomarkers of exposure are generally the substance itself or substance-specific metabolites in readily obtainable body fluid(s) or excreta. DDT and its metabolites DDD,DDE, DDA, and MeSO2-DDE (3-methylsulphonyl-DDE), can be measured in adipose tissue, blood serum, urine, feces, semen, or breast milk .

Breast Milk

Psychological and medical studies have underlined the benefits of nursing which raises immunological defenses and provides a healthier development of the baby. Parallel findings have increased concern about the excretion of drugs and environmental contaminants contained in breast milk, since it is considered the main route for eliminating deposited organochlorine pesticides from a mother's body (Jensen and Slorach 1991; Sonawane 1995; Cupul-Uicab et al. 2008).

Because of their lipophilic nature and high persistence, DDT and its metabolites accumulate in lipophilic human body parts, particularly in lipid-rich tissues such as adipose tissue and subsequently translocated and excreted through milk fat. A major concern is that milk is the first (and in some areas the only) food for the newborn child.

Concentrations of DDTs (DDT, DDD and DDE) in human milk have been shown to be higher in communities exposed to this insecticide, than in non-exposed populations (Table 10). For example, levels from a cotton area where DDT was used for agricultural purposes (Coahuila) were higher or similar to those obtained in samples collected in a malarious area (Veracruz, Yucatan) where DDT was extensively used (Table 10). And both were higher than the concentrations quantified in urban areas (Mexico DF), where DDT has never been used.

The World Health Organization's Acceptable Daily Intake (ADI) for DDTs is 20 mg/kg/day (Lu 1995). In this regard, considering a body mass of 5 kg, a milk intake of 0.85 kg/day, a proportion of fat in milk of 0.035, and a DDT concentration in milk of 10.4 mg/kg (total DDT concentration in samples collected during 1996 1997 in a suburban malarious area; Albert et al. 1980), the estimated daily intake is three times higher than the ADI. Furthermore, if the maximum range concentration found in some studies (36.5 mg/kg; Albert et al. 1980) is taken into account, the ADI is surpassed 11 times. However, when calculated the ADI with DDT concentration in milk of 2.4 mg/kg (Waliszewski et al. 2009), the ADI calculated is lower than 20 mg/kg/day. It is important to remark that the chronological levels obtained by Waliszewski et al. (1996, 1999, 2001, 2002, 2009) have a decreasing tendency. That result coincides with the restriction and prohibition for DDT use in Mexico.

Serum

In this document, we presented data regarding DDT and its metabolites levels in children (Table 11) and adults (Table 12)

Children appear to be particularly suitable for a monitoring program, as they are not directly exposed to occupational pollution; thus, children normally reflect present trends of environmental exposure more accurately than do adults (Link et al., 2005). Moreover, it is well established that children are potentially at a higher risk than adults for adverse health effects from exposure to many environmental chemicals (Guzelian et al., 1992; Bearer, 1995; Carlson, 1998; Galson et al., 1998; Aprea et al., 2000; Needham and Sexton, 2000; Adgate and Sexton, 2001; Brent et al., 2004; IPCS, 2006).

Location	Total DDT	Region	Reference
Coahuila	10400.0	North	Albert et al. 1980
Mexico DF	900.0	Central	Torres-Arreola et al. 1999
Veracruz	7815.0	Southeastern	Pardio et al. 1998
Veracruz	6280.0	Southeastern	Waliszewski et al. 1996
Veracruz	4700.0	Southeastern	Waliszewski et al. 1999
Veracruz	4700.0	Southeastern	Waliszewski et al. 2001
Veracruz	3740.0	Southeastern	Waliszewski et al. 2002
Morelos	4320.0	Central	Lara et al. 2000
Yucatan	3065.0	Southeastern	Rodas-.Ortíz et al. 2008
Veracruz	2335.0	Southeastern	Waliszewski et al. 2009

Table 10. Total DDT levels in human milk (ng/g lipid) in different Mexican Regions.

Adipose tissue

Adipose tissue biopsy has been used in epidemiological studies to assess chronic exposure to DDT. This is a logical choice because the DDTs are accumulated in adipose tissue due to its lipid solubility. The half-life of DDT in human adipose tissue is approximately seven years (Woodruff et al. 1994).

As in serum, DDTs in adipose tissue are a good biomarker of exposure for communities exposed to DDT. When compared to an urban non-exposed community [46], the levels of DDTs (especially those of DDE), were higher in the exposed population (Table 9). In the same table it can be observed that the concentrations of DDT in adipose tissue from workers of the malaria program were higher than the levels found in people living in an agricultural area or in malarious areas. In the workers, a linear model that included an index of chronic exposure, the use of protective gear,and recent weight loss explained 55% of the variation of

p,p′-DDE conncentrations in adipose tissue. The index of chronic exposure was constructed according to worker position and based on the historical duration and intensity of DDT application [48].

When the concentrations of DDTs in adipose tissue were expressed by age group, two groups were identified as the most exposed. Those groups were children and elderly people [49]. The levels in elderly people can be explained by the accumulation of DDT in a chronic exposure scenario,whereas the concentration in children may be the result of an exposure to multiple pathways (soil, household dust, air, water, food, etc.). It is interesting that the group less exposed to DDT was the 0–2 years, a group that may be exposed to DDT through lactation [49].

Location	Total DDT (ng/g lipid)	Region	Reference
Chiapas	22280.0	Southeastern	Trejo-Acevedo et al. 2009
Oaxaca	7500.00	Southeastern	Perez-Maldonado et al. 2006
Quintana Roo	11300.0	Southeastern	Perez-Maldonado et al. 2006
Chihuahua	35000.00	North	Díaz-Barriga et al. 2011
Queretaro	2170.0	Central	Trejo-Acevedo et al. 2009
Durango	2270.0	North	Trejo-Acevedo et al. 2009
San Luis Potosí	1990.0	Central	Trejo-Acevedo et al. 2009
Guanajuato	940.0	Central	Trejo-Acevedo et al. 2009
Veracruz	1910.0	Southeastern	Trejo-Acevedo et al. 2009
Michoacan	550.0	Central	Trejo-Acevedo et al. 2009
Zacatecas	700.0	Central	Trejo-Acevedo et al. 2009

Table 11. Total DDT levels in serum (ng/g lipid) of children living in different Mexican Regions.

A monitoring program of DDTs in adipose tissue is needed in order to assess the body burden, now that in Mexico this insecticide has been eliminated from the malaria program. However, due to ethical constraints, it is not always possible to obtain adipose tissue samples form healthy individuals. Therefore, alternative matrices are needed; for example, a good correlation between adipose tissue concentration and levels in human milk [50] or human serum [51] has been reported .When the geometric DDE levels in lipid bases are used for the estimation of the adipose tissue/serum DDE ratio, a value near unity is obtained [51].

5. Health effects

DDT and its metabolites have been associated with neurological effects (Dorner and Plagemann 2002; Fenster et al. 2007; Torres-Sánchez et al. 2007; Rocha-Amador et al. 2009), asthma (Sunyer et al. 2006), immunodeficiency (Dewailly et al. 2000; Vine et al. 2000; Vine et al. 2001; Belles-Isles et al. 2002; Bilrha et al. 2003; Cooper et al. 2004; Dallaireet al. 2004), apoptosis (Pérez-Maldonado et al. 2004) and DNA damage in immune cells in children (Yáñez et al. 2004; Herrera-Portugal et al. 2005b).

Location	Total DDT (ng/g lipid)	Region	Reference
Chiapas	12750.0	Southeastern	Yañez et al. 2002
Oaxaca	8050.0	Southeastern	Yañez et al. 2002
Tabasco	8700.0	Southeastern	Torres-Dosal et al. 2011
Mexico, DF	20.0	Central	Lopez-Carrillo et al. 1997
Veracruz	4500.00	Southeastern	Waliszewski et al. 2000
Morelos	20.0	Central	Lopez-Carrillo et al. 2001
San Luis Potosí	1715.0	Central	Yañez et al. 2004

Table 12. Total DDT levels in serum (ng/g lipid) of adults living in different Mexican Regions.

Location	Total DDT	Region	Reference
Coahuila	18400.0	Central	Albert et al. 1980
Mexico DF	6100.0	Central	Albert et al. 1980
Puebla	2700.0	Central	Albert et al. 1980
Veracruz	10000.0	Southeastern	Waliszewski et al. 1996
Veracruz	61000.0	Southeastern	Rivero-Rodriguez et al. 1997
Veracruz	5700.0	Southeastern	Waliszewski et al. 2001
Veracruz	2600.0	Southeastern	Waliszewski et al. 2010
Puebla	800.0	Central	Waliszewski et al. 2010
Veracruz	1900.0	Southeastern	Waliszewski et al. 2011
Veracruz	1400.0	Southeastern	Herrero-Mercado et al. 2010
Veracruz	900.0	Southeastern	Herrero-Mercado et al. 2011

Table 13. Total DDT levels in Adipose Tissue (ng/g lipid) of adults living in different Mexican Regions.

5.1 Cancer

Although it has been suggested that the estrogenic activity of DDE may be a contributing factor for development of breast cancer in women, levels of these compounds are not consistently elevated in breast cancer patients. It was initially reported that levels of *p,p*2-DDE were elevated in breast cancer patients (serum or tissue) versus controls [52].More recent studies and analysis of organochlorine levels in breast cancer patients versus controls

show that these contaminants are not elevated in the latter group [53–56]. The study of occupationally exposed workers has not found clear increased risks for other cancers [57].
Two case-control studies of breast cancer have been carried out in Mexico City, with conflicting results. The first study, conducted by Lopez-Carrillo et al. [58] in Mexico City, compared 141 cases of breast cancer with 141 age-matched controls. All subjects were identified at three referral hospitals between March 1994 and April 1996. The arithmetic mean of serum DDE in lipid basis was 562 ppb±676 for the cases and 505 ppb±567 for the controls.The age-adjusted odds ratios for breast cancer regarding the serum level of DDE were 0.69 (95% confidence interval, 0.38–1.24) and 0.97 (CI, 0.55–1.70) for the contrasts between tertile 1 (lowest level) and tertiles 2 and 3, respectively. These estimates were unaffected by adjustment for body mass, accumulated time of breast-feeding and menopause, and other breast cancer risk factors. These results do not lend support to the hypothesis that DDT is causally related to breast cancer. The second study conducted by Romieu et al. [59] compared 120 cases and 126 controls, selected from six hospitals in Mexico City, from 1989 to 1995. Serum DDE levels in lipid basis were higher among cases (mean=3840 ppb±5980) than among controls (mean=2510 ppb±1970).After adjusting for age, age at menarche,duration of lactation, Quetelet index, and serum DDT levels, serum DDE levels were positively r elated to t he risk for b reast cancer (adjusted O R_{Q1-Q2}=1.24), 382 F. Díaz-Barriga et al. (CI, 0.50–3.06; OR_{Q1-Q3}=2.31, 95 percent, CI, 0.92–5.86; OR_{Q1-Q4}=3.81, CI, 1.14–12.80). The increased risk associated with higher serum DDE levels was more apparent among postmenopausal women (OR_{Q1-Q4}=5.26, 95%, CI, 0.80–34.30). Serum DDT level was not related to the risk for breast cancer. In addition to the differences in the comparison of cases and controls, the difference in the serum DDE levels among the women studied is remarkable. Participants from both studies came from similar hospitals, and there were no apparent differences between case and control selection that could explain this divergence. Differences in laboratory procedures is the most feasible explanation.

5.2 Endocrine disruption

DDT is known to have adverse effects on wildlife via endocrine disruption.Clear effects include thinning of the eggshell, feminization, reproduction impairment and development effects [60]. In Mexico two studies in humans have reported findings in this area. Gladen and Rogan [61] found that DDE might affect women's ability to lactate in a study conducted in an agricultural town in northern Mexico. Two hundred and twenty-nine women were followed from childbirth until weaning or until the child reached 18 months of age.DDE was measured in breast milk samples taken at birth, and women were followed to see how long they lactated.Median duration was 7.5 months in the lowest DDE group and 3 months in the highest. The effect was confined to those who had lactated previously – but not for first pregnancies – and it persisted after statistical adjustment for other factors. Rodriguez et al. [62] conducted a study aimed at determining the capability of long-term exposure to DDT of altering the normal endocrine function of the hypothalamus-hypophysis-gonads axis in humans. This included 70 workers dedicated to control malaria in the State of Guerrero,Mexico. The main activities of these workers were the application of pesticides,detection of malaria cases and promotion of preventive measures for control vectors. The average time of exposure to technical grade DDT was 25 years (range: 4–35), their last exposure being 5 months before sampling. An interview gathered information on the occupational history, reproductive performance, life styles and other relevant factors. Blood and urine samples were collected to measure serum levels of DDT and metabolites as

well as levels of LH, FSH, prolactine, and testosterone. Participants ranged in age from 22 to 69 years, and had been employed in the sanitation campaign from 4 to 37 years. Ninety-seven percent of the participants were sprayers of DDT at some time in their occupational history, and 15% are current sprayers. Average levels of DDT and metabolites expressed as μg/g of extractable lipids were: total DDT, 60.1; *p*,*p*2-DDE, 37.41; *p*,*p*2-DDT, 21.52; *p*,*p*2-DDD, 1.07 and *o*2*p*-DDT 0.11. Results show a positive association of LH and FSH with DDT metabolites. An increase of 10 *m*g/g of *p*,*p*2-DDE was associated with an increase of 1.95 UI/L in LH (p=0.01); and 1.10 UI/L per each 10 *m*g/g of *p*,*p*2-DDT (p=0.02). FSH increased 1.09 UI/L per each 10 *m*g/g of *p*,*p*2- DDT (p=0.03). There was a negative association of DDE with testosterone, DDT in Mexico 383 especially for those participants under 55 years of age. These associations suggest direct toxicity to the testicles, especially the Leydig cells, as observed with antineoplasic drugs.

5.3 Genotoxicity

Some studies have reported genotoxic effects in humans heavily exposed to DDT [8]. Therefore, this area has been studied in Mexico. Studies were done in workers from the control program of malaria, and in women living in malarious areas. Herrera et al. [63] evaluated chromosomal translocations in a sample of the above-mentioned workers.Nineteen male sprayers (median age 46 years; range: 22–64),working in campaigns to control malaria vectors in the state of Guerrero, Mexico were included in this study.DDT data obtained in a previous study from eleven individuals, 5 women and 6 men, living in Mexico City, and occupationally unexposed to DDT were used as reference group. Chromosomal aberrations in lymphocytes were analyzed with a chromosome painting technique, a highsensitivity technique for detecting complex chromosomal translocations. *o*,*p*2- DDT was the only isomer significantly associated with the frequency of chromosomal translocations (p=0.003). Individuals presenting the higher levels of *o*,*p*2-DDT in serum (>0.79 *m*g/g fat; n=4) had a mean frequency of chromosomal translocations (5.1¥1000 metaphases), two times higher than that observed in workers occupationally exposed to 0.5 Gy of radiation.A positive relationship between the duration of exposure to DDT, measured as years working for the vector control program, and chromosomal translocations was observed (Fig.2). These results suggest an increased risk for diseases with a genetic component, such as cancer.

Yañez et al. [64] evaluated the association of blood DDT levels and DNA damage using the single cell gel electrophoresis assay. A group of 53 postpartum women were selected from two different areas in San Luis Potosí to assure different exposure levels, one with antecedents of malaria and DDT spraying and the other without malaria. Mean and range levels of DDT, DDE and DDD in whole blood were 5.57 ppm (0.02–20.69), 6.24 ppm (0.04–39.16) and 1.16 ppm (0.01–5.63), respectively. The significant correlation of DNA damage, measured as DNA migration with the logarithm of DDT,DDE and DDD was 0.60, 0.62 and 0.43, respectively. Fig. 3 shows the shape of the association of DNA migration with DDE concentration in whole blood, as obtained by the regression: DNA migration= 71.58+7.62(logDDE), this association was not modified by age, smoking habits, nutrition or occupation. This observational finding in the epidemiological study with postpartum women was reevaluated in an in vitro study.Human blood cells were exposed to three doses of DDT, DDD and DDE.DNA damage was assessed by two different techniques: single-cell electrophoresis and flow cytometry. Results obtained by either technique showed that DNA damage was induced by the three organochlorides and a dose-response was observed with

DDT. The data suggest a DDT-induced DNA fragmentation, and this outcome was also observed with DDE and DDD.

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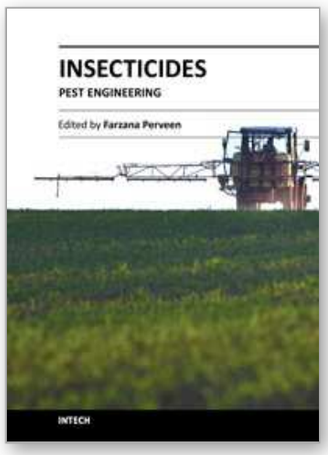

Insecticides - Pest Engineering

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This book is compiled of 24 Chapters divided into 4 Sections. Section A focuses on toxicity of organic and inorganic insecticides, organophosphorus insecticides, toxicity of fenitrothion and permethrin, and dichlorodiphenyltrichloroethane (DDT). Section B is dedicated to vector control using insecticides, biological control of mosquito larvae by Bacillus thuringiensis, metabolism of pyrethroids by mosquito cytochrome P40 susceptibility status of Aedes aegypti, etc. Section C describes bioactive natural products from sapindacea, management of potato pests, flower thrips, mango mealy bug, pear psylla, grapes pests, small fruit production, boll weevil and tsetse fly using insecticides. Section D provides information on insecticide resistance in natural population of malaria vector, role of Anopheles gambiae P450 cytochrome, genetic toxicological profile of carbofuran and pirimicarp carbamic insecticides, etc. The subject matter in this book should attract the reader's concern to support rational decisions regarding the use of pesticides.

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