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Organochlorine pesticides in elementary school yards along the Texas–Mexico border

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"Capsule": *Soils from elementary school yards could serve as a source of pesticide exposure for children.*

Abstract

A reconnaissance study was undertaken to determine potential contaminant exposures to children through soil from elementary school playgrounds. Soil samples were collected from areas along the Texas–Mexico border, inland areas (soils from elementary school yards in cities/towns within the state of Texas), and three National Parks (one on the border, one in Tennessee, and one in Washington). The present study focused on organochlorine (OC) pesticides as the potential contaminants of concern because of their historical (and possibly current) use, and their importance as persistent organic pollutants (POPs). DDE and heptachlor were the most frequently detected OCs (69 and 63%, respectively), although heptachlor concentrations in soil never exceeded 5 ppb. Relatively higher concentrations of DDE were observed in agricultural areas along the border (50–60 ppb in soils from McAllen, Palmview, and San Benito) than in other soils. However, a school yard in Lubbock, TX had the highest OC concentration observed (70 ppb dieldrin). These results may be due to historical agriculture activity prior to the banning of OC pesticides such as DDT in the early 1970s, as well as the more recent use of DDT in Central and South America for malaria control.

Keywords: DDE; Pesticides; School yards; Texas–Mexico border; Soil; POPs

1. Introduction

Health risks along the Texas–Mexico border region are an ongoing concern. The passage of the North American Free Trade Agreement and subsequent population growth in Mexico's boomtowns and Texas' *colonias* may exacerbate these risks, as accelerated growth has led to poorer living conditions and increased exposures to a variety of opportunistic diseases, toxic chemicals, and other health hazards (Liverman et al., 1999; Atkinson, 2001). Accumulating epidemiologic evidence suggests that environmental risk factors such as rural residency and exposure to pesticides contribute to disease onset or progression, thus it is likely that certain human populations living in immutable conditions along the border region face enhanced lifetime exposures to environmental contaminants. Additionally, it is also likely that certain ethnic minorities, particularly Mexican-Americans, face enhanced lifetime exposures attendant upon agricultural occupations.

Recently, the US–Mexico Border Health Commission has been charged with the development of a comprehensive, long-term strategic plan for monitoring health risks, identifying major health care issues, and developing corrective actions for health care problems along the border. Among such efforts are goals to improve the understanding of environmental exposures and risks to residents along the border and to develop management practices that reduce those exposures and risks where they exist. Environmental problems in the border region are well documented and include air pollution in the major "sister cities" of the entire border, contamination of the Rio Grande with pesticide residues, potential toxic exposures within the *colonias*, and industrial toxicant releases on both sides of the border (Liverman et al., 1999).

In an effort to begin to identify and assess potential contaminant exposures to children, we collected soil samples from reference areas and playgrounds of elementary schools, and screened those soil samples for organochlorine (OC) pesticide residues. Soil sampling

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was focused on areas along the Texas–Mexico border, but also included elementary school yards from inland areas in Texas with varying agriculture histories. We focused our screening efforts on OCs because of their importance as persistent organic pollutants (POPs). In general, POPs such as OC pesticides are receiving international attention and most recently new resolutions designed to eliminate and restrict POP use (Mintz, 2001) were drafted at the Convention on Persistent Organic Pollutants (UNEP Chemicals, 2001). Although OC pesticides were banned for use in the United States, between the late 1940s and early 1970s these chemicals were widely applied in the United States to control nuisance insect populations and continue to be used in Mexico. OCs have long half-lives and high sorption coefficients which allows for prolonged exposure scenarios even in areas where these chemicals are no longer applied (Muir et al., 1988; Fraser et al., 2002). They also accumulate in fat depots.

2. Materials and methods

2.1. Sample collection

Surface soils (top 30 cm) were collected using a trowel primarily from elementary school yards in eight cities/towns (El Paso, Harlingen, La Joya, McAllen, Palmview, San Benito, Sullivan City, and Laredo) along the Texas side of the border (Fig. 1). Additional soil samples were collected from elementary school yards in towns within the state of Texas: Abilene, Albany, Corpus Christi, Lubbock, and Midland. Soils considered as ‘‘reference’’ were collected from three national parks in Tennessee (Great Smoky Mountains), Texas (Big Bend), and Washington (Olympic). A brief description of sample locations is provided in Table 1. For anonymity, the elementary school yards from each location where soil was collected were assigned a code. Soil samples ($N=64$) were stored in sterile Whirlpak® bags until processing.

2.2. Soil extraction

Soil samples were air dried and sieved (2 mm) prior to extraction. Accelerated solvent extraction (ASE) was used to extract the soil. Approximately 12–15 g of soil was mixed with anhydrous sodium sulfate, transferred to 33-ml extraction cells, and fortified with an internal standard containing tetrachloro-meta-xylene (TCMX) and decachlorobiphenyl (DCBP). The soil samples were extracted with 50:50 hexane:acetone (organic solvents were pesticide or GC/MS grade) using a Dionex 200 ASE (Dionex Corp.) under the following conditions: pressure = 1500 psi, temperature = 100 °C, extraction time = 15 min. Extracts were collected in 60-ml glass

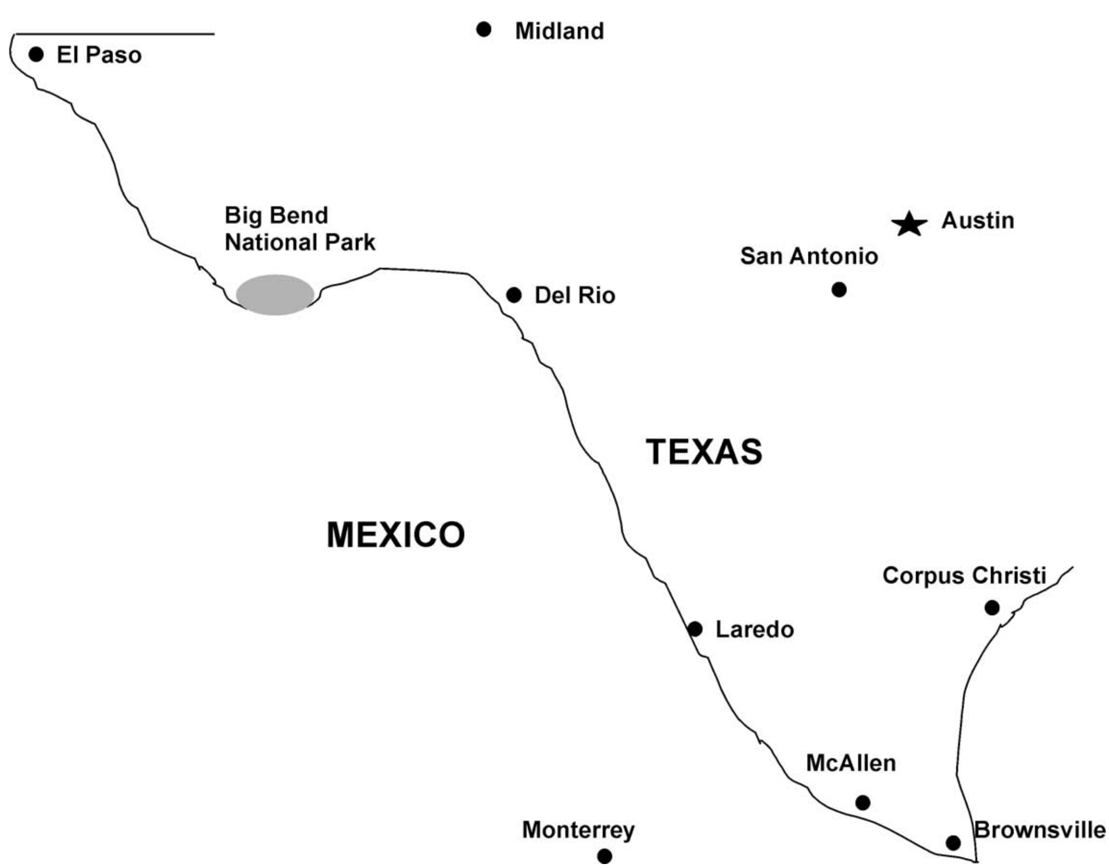

Fig. 1. Map of the Texas–Mexico border region.

Table 1
Descriptions of locations from which samples were collected for studies on organochlorine pesticide concentrations in soils from elementary school yards along the Texas–Mexico border and reference areas

Location	Description
El Paso, TX	Border city dominated by industry with minimal agriculture
Harlingen, TX	Border city in agricultural area between McAllen and Brownsville
La Joya, TX	Small border town in agricultural area near McAllen
McAllen, TX	Border city in agricultural area
Palmview, TX	Small border town in agricultural area near McAllen
San Benito, TX	Border town in agricultural area near Brownsville
Sullivan City, TX	Small border town in agricultural area near McAllen
Corpus Christi, TX	Coastal city in agricultural area
Lubbock, TX	Inland city with extensive current and historical agricultural (cotton) activity, 300 miles north of Del Rio
Laredo, TX	Border city of international commerce with minimal agricultural activity
Abilene, TX	Inland city with moderate current and historical agricultural activity, 325 miles north of Laredo
Midland, TX	Inland city of oil production with minimal agricultural activity, 200 miles north of Big Bend National Park
Albany, TX	Inland town of oil production and ranching with minimal agricultural activity, 345 miles north of Laredo
Tennessee Reference	Great Smoky Mountains National Park: High elevation woodland
Texas Reference 1	Site along Pine Canyon watershed in Big Bend National Park: Low desert scrub
Texas Reference 2	Site along Pine Canyon watershed in Big Bend National Park: High elevation woodland
Washington Reference	West Twin Creek watershed in Olympic National Park: Hemlock-dominated stand

vials with Teflon® caps. Extract volumes were reduced to 2 ml using rotary evaporation. The extracts were then cleaned using solid phase extraction (SPE) cartridges containing florisil. Eluates were brought to volume (2 ml), filtered (0.45 μm Acrodisc®), and transferred to autosample vials. Extraction efficiency, as indicated by recovery of the internal standards (TCMX and DCBP), was consistently $>80\%$.

2.3. Residue analysis

A Hewlett-Packard 6890 gas chromatograph equipped with a ^{63}Ni electron capture detector (ECD) and a 30 m×0.32 mm DB-5 column was used to separate and quantify the OCs. Inlet and detector temperatures were 230 and 250 °C, respectively. The temperature program was as follows: initial temperature was 100 °C; increased from 100 to 180 °C at 25 °C/min; increased from 180 to 230 °C at 5 °C/min with a 2-min hold; increased from 230 °C to a final temperature of 300 °C at 20 °C /min with an 8-min hold. OCs were identified by retention time matches to standards and were quantified using peak area integration. The standard OC pesticide mixture used to screen soil extracts contained the following compounds: TCMX, heptachlor, γ-BHC (lindane), dieldrin, endrin, aldrin, *p,p*-DDD, *p,p*-DDT, methoxychlor, *p,p*-DDE, and DCBP. The detection limit for the OCs in soil was approximately 0.5 ppb.

3. Results

3.1. Soil samples from all locations

Overall, soil concentrations of OCs ranged from ND (not detected) to 70 ppb (Table 2). DDE (69% positive), a persistent metabolite of DDT, and heptachlor (63% positive) were the most frequently detected OCs in this study. Both DDE and heptachlor were detected in soils from all three location types: border areas, inland areas, and reference areas. Lindane, aldrin, DDD, and methoxychlor were the least frequently detected OCs: 6, 3, 5, and 5%, respectively.

3.2. Reference and inland soils

In order to determine background OC levels and to better characterize detectable OC contaminants, reference soil samples were collected. Big Bend National Park, which served as the Texas reference site, is located along the Texas–Mexico border. OC contaminants detected from these reference soils (Table 2) ranged from ND to 23 ppb (DDT in soil from the Lost Mine area at Big Bend National Park). DDE (6 and 9 ppb) was detected in reference soils from Tennessee's Great Smoky Mountains National Park. Heptachlor (100%) and DDE (88%) were the most frequently detected OCs in the reference soils. Aldrin and DDD were not detected in any of the reference soils.

In addition to reference soils, we also collected soils from elementary school yards in cities/towns within the state of Texas. These school yards were located in cities that currently have or had strong historical associations with agriculture, ranching, or oil production. OC levels in these soils (Table 2) ranged from ND to 70 ppb (dieldrin in soil from an elementary school playground in Lubbock, TX). Most of the remaining inland soil samples had OC concentrations at trace levels or below detection. Heptachlor (68%), DDE (63%), dieldrin (53%), and DDT (53%) were the most frequently detected OCs in these soils.

Table 2
Organochlorine pesticide concentrations in soils from elementary school yards along the Texas–mexico border, inland areas in Texas, and reference areas

Location	Contaminant (ng/g)								
School[a]	Lindane	Heptachlor	Aldrin	DDE	Dieldrin	Endrin	DDD	DDT	Methoxychlor
El Paso									
Alpha	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bravo	ND	ND	ND	ND	ND	ND	ND	ND	ND
Charlie	ND	ND	ND	ND	ND	ND	ND	ND	ND
Delta 1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Delta 2	ND	Trace	ND	ND	ND	ND	ND	ND	ND
Echo 1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Echo 2	ND	Trace	ND	Trace	ND	ND	ND	Trace	ND
Foxtrot 1	ND	Trace	ND	ND	ND	ND	ND	ND	ND
Foxtrot 2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Golf 1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Golf 2	ND	ND	ND	ND	ND	ND	ND	ND	ND
Harlingen									
Alpha 1	ND	ND	ND	1	ND	ND	ND	ND	ND
Alpha 2	ND	2	ND	2	ND	ND	ND	ND	ND
Bravo 1	ND	ND	ND	6	1	3	ND	4	ND
Bravo 2	ND	ND	ND	3	ND	ND	ND	ND	ND
Charlie 1	ND	ND	ND	2	ND	ND	ND	ND	ND
Charlie 2	ND	ND	ND	20	ND	ND	ND	ND	ND
La Joya									
Alpha 1	ND	1	ND	2	Trace	2	ND	3	ND
Alpha 2	ND	ND	ND	2	ND	ND	ND	ND	ND
Bravo 1	ND	1	ND	Trace	ND	ND	ND	ND	ND
Bravo 2	ND	1	ND	1	ND	ND	ND	ND	ND
Laredo									
Alpha	ND	1	ND	Trace	Trace	ND	ND	ND	ND
Bravo	ND	1	ND	7	Trace	ND	ND	2	ND
Charlie	ND	Trace	ND	Trace	ND	ND	ND	ND	ND
McAllen									
Alpha 1	2	2	ND	10	1	3	ND	2	ND
Alpha 2	ND	1	ND	10	ND	ND	ND	ND	ND
Bravo	ND	1	ND	50	ND	6	ND	ND	3
Palmview									
Alpha 1	ND	2	ND	60	ND	ND	ND	ND	ND
Alpha 2	ND	1	ND	60	ND	ND	ND	ND	ND
Bravo 1	ND	ND	ND	1	ND	ND	ND	ND	ND
Bravo 2	ND	ND	ND	2	ND	ND	ND	ND	ND
Charlie	ND	1	ND	ND	ND	ND	ND	ND	ND
San Benito									
Alpha 1	ND	ND	ND	60	ND	ND	ND	10	ND
Alpha 2	ND	ND	ND	20	ND	ND	ND	3	ND
Bravo 1	ND	5	ND	4	ND	ND	ND	ND	ND
Bravo 2	ND	ND	ND	2	ND	ND	ND	ND	ND
Sullivan City									
Alpha	ND	1	ND	ND	Trace	2	ND	2	ND
Summary (Border areas)									
% Positive	**3%**	**49%**	**0%**	**68%**	**16%**	**14%**	**0%**	**22%**	**3%**
Range	**ND–2**	**ND–5**	**ND**	**ND–60**	**ND–1**	**ND–6**	**ND**	**ND–10**	**ND–3**

(*continued on next page*)

Table 2 (*continued*)

Location	Contaminant (ng/g)								
School[a]	Lindane	Heptachlor	Aldrin	DDE	Dieldrin	Endrin	DDD	DDT	Methoxychlor
Abilene									
Alpha 1	Trace	1	ND	ND	Trace	Trace	ND	ND	ND
Alpha 2	ND	Trace	ND	ND	ND	ND	ND	ND	ND
Bravo 1	ND	1	ND	Trace	Trace	Trace	ND	ND	ND
Bravo 2	ND	Trace	ND	ND	ND	ND	Trace	Trace	ND
Albany									
Alpha 1	ND	Trace	ND	Trace	Trace	ND	ND	ND	ND
Alpha 2	ND	1	ND	Trace	Trace	ND	ND	ND	ND
Corpus Christi									
Alpha	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bravo	ND	ND	ND	ND	ND	ND	ND	2	ND
Charlie	ND	ND	ND	Trace	ND	ND	ND	1	ND
Midland									
Alpha	ND	Trace	ND	1	ND	ND	ND	ND	ND
Bravo	ND	1	Trace	Trace	Trace	ND	ND	Trace	ND
Charlie	ND	1	ND	Trace	Trace	ND	ND	ND	ND
Delta	ND	3	ND	4	Trace	ND	1	5	ND
Echo	ND	Trace	ND	Trace	Trace	ND	Trace	Trace	Trace
Lubbock									
Alpha	ND	ND	ND	10	ND	1	ND	ND	ND
Bravo 1	ND	Trace	ND	3	ND	ND	ND	1	ND
Bravo 2	ND	Trace	ND	2	ND	ND	ND	1	ND
Charlie 1	ND	ND	ND	ND	70	ND	ND	2	ND
Charlie 2	ND	ND	Trace	ND	20	ND	ND	1	ND
Summary (Inland areas)									
% Positive	**5%**	**68%**	**11%**	**63%**	**53%**	**16%**	**16%**	**53%**	**5%**
Range	**ND–Trace**	**ND–3**	**ND–Trace**	**ND–w10**	**ND–70**	**ND–1**	**ND–1**	**ND–5**	**ND–Trace**
National Parks									
Lost Mine 1	1	3	ND	4	ND	ND	ND	23	ND
Lost Mine 2	Trace	1	ND	1	ND	ND	ND	1	2
Great Smokey 1	ND	1	ND	6	ND	Trace	ND	ND	ND
Great Smokey 2	ND	3	ND	9	Trace	1	ND	3	ND
West Twin 1	ND	3	ND	ND	ND	ND	ND	ND	ND
West Twin 2	ND	Trace	ND	Trace	ND	ND	ND	ND	ND
Glenn Springs 1	ND	Trace	ND	Trace	ND	ND	ND	ND	ND
Glenn Springs 2	ND	5	ND	Trace	ND	ND	ND	ND	ND
SUMMARY (Reference areas)									
% Positive	**25%**	**100%**	**0%**	**88%**	**13%**	**25%**	**0%**	**38%**	**13%**
Range	**ND–1**	**Trace–5**	**ND**	**ND–9**	**ND–Trace**	**ND–1**	**ND**	**ND–23**	**ND–2**
Summary (All areas)									
% Positive	**6%**	**63%**	**3%**	**69%**	**27%**	**16%**	**5%**	**33%**	**5%**
Range	**ND–2**	**ND–5**	**ND–Trace**	**ND–60**	**ND–70**	**ND–6**	**ND–1**	**ND–23**	**ND–3**

ND, non-detectable (detection limit = 0.5 ppb); Trace, detected, but not quantified.

[a] All school names were assigned a code in order that the locations remained anonymous.

3.3. Border soils

Elementary school yards in the border towns of Palmview, San Benito, Harlingen, and McAllen all had relatively high concentrations of DDE (60, 60, 20, and 50 ppb, respectively) compared with soils from other locations in this study. Soils from elementary school yards in other border areas had lower OC residues ($\leqslant$10 ppb). DDE (68%) and heptachlor (49%) were the most frequently detected OCs in these soils. Aldrin and DDD were not detected in any of the border soils. Nearly all of the samples collected from seven elementary school yards in El Paso were negative for OCs.

4. Discussion

Our results indicate that OC pesticides are present in surface soils from elementary school yards. A persistent metabolite of DDT (DDE) was the most frequently detected OC. Although heptachlor was also frequently detected in soils from elementary school yards, the concentrations of heptachlor in these soils was relatively low (range = ND–5 ppb). The highest OC concentration was observed in a soil sample collected from an elementary school yard in Lubbock, TX (dieldrin, 70 ppb).

Due in large part to the Green Revolution and the cotton boom of the 1960s, large amounts of organochlorine pesticides have been applied in Latin American regions (Castillo et al., 1997). Latin American pesticide policy and use may contribute to OC contamination along the Texas–Mexico Border (Zahedi, 1999; Murray, 1994). Soils collected from elementary school yards along the border had relatively higher concentrations of DDE, especially near agricultural areas (Harlingen, McAllen, Palmview, San Benito). These results may be due to the area's historical agriculture activity prior to the banning of DDT in the early 1970s, as well as more recent use of DDT in Mexico for malaria control (Lopez-Carillo et al., 1996). It is important to note that school yard soils from Lubbock, TX, an area with an extensive agricultural history, also had DDE (up to 10 ppb) and dieldrin (20 and 70 ppb). Soil samples collected from reference areas (National Parks) had slightly less but similar concentrations of OCs as inland soils.

Monitoring data on DDT and its metabolites in soil is relatively scarce in the literature. However, historical data obtained during the time of DDT use are relevant to the present study in putting the school yard data in context. These historical data indicate that DDE concentrations in soil (2 seperate studies of 5 and 8 US cities) ranged from 0.01 to 7.9 ppm (Carey et al., 1978) and 0.1 to 53 ppm (Wiersma et al., 1972), respectively. In addition, more recent data indicate that DDE was also detected in sediment samples from three coastal lagoons in the Gulf of Mexico (0.2–1.8 ppb; Albert, 1996). Although usually well below regulatory levels, DDT is commonly detected in food items, especially fruits and vegetables, under the Food and Drug Administration's pesticide monitoring studies (1995; Gunderson, 1995).

This study indicates that soils from elementary school yards could serve as a source of OC pesticide exposure to children. While exposure to OCs in school yard soils would be assumed to occur via ingestion and dermal contact, it is not clear from the present study how biologically available the OCs are to children using these areas. It is well known that with time, these contaminants become less biologically available in soil (Awata et al., 1999, 2000) and that residue data based on rigorous extraction and analysis may overestimate the risk to terrestrial organisms. EPA risk assessment guidelines assume that the soil ingestion rate for all individuals over age 7 to be 100 mg soil/day (US EPA, 1989) and that soil DDT concentrations are 1 mg DDT_{tot}/kg soil (1 ppm). We did not detect any OC contaminants in the ppm range, and all samples were well below permissible risk-based levels. Further characterization (concentrations, availability) of OCs (and other contaminants) in soils from these and other areas well help provide additional insight into this potential exposure pathway for children. Such characterization would be very beneficial in understanding the potential additive and synergistic effects these chemicals have on border populations.

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