Biological Monitoring of Pesticide Exposures among Applicators and Their Children in Nicaragua

TERESA RODRÍGUEZ, MD, LISA YOUNGLOVE, MPH, CHENSHENG LU, PHD, AURA FUNEZ, SARAH WEPPNER, MS, DANA B. BARR, PHD, RICHARD A. FENSKE, PHD, MPH

Exposures were assessed for seven small-scale farmers using chlorpyrifos on corn and ten banana plantation employees applying diazinon, and for one child of each worker. Metabolites (TCPY and IMPY) were measured in urine before and after applications. TCPY concentrations peaked at 27 and 8.5 hours post-application for applicators and children, respectively (geometric means, 26 and 3.0 µg/L). Proximity to spraying and spray mixture preparation in homes were important exposure factors. IMPY concentrations differed substantially across workers at two plantations (geometric means, 1.3 and 168 µg/L); however, their children had little or no diazinon exposure. These workers and children were also exposed to chlorpyrifos, most likely through contact with chlorpyrifos-impregnated bags used in banana production. Several recommendations are offered: 1) monitor children's activities during applications; 2) do not store or prepare pesticides in homes; 3) institute sound occupational hygiene practices at banana plantations; 4) dispose of plastic insecticide bags properly at the worksite. *Key words*: pesticide exposure; Nicaragua; chlorpyrifos; diazinon; urinary metabolite; biological monitoring; applicators; children.

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Address correspondence and reprint requests to: Richard Fenske, Department of Environmental and Occupational Health Sciences, Box 357234, Health Sciences Building Room F-233, 1959 NE Pacific Street, Seattle, WA 98195, U.S.A.; telephone (206) 543-0916; e-mail: <rfenske@u.washington.edu>.

Children who live in agricultural communities have been a focus of periodic public health investigations, since they may have higher exposures to pesticides than children in non-agricultural regions.[1–15] A study of agricultural workers and their children in Washington State first documented a para-occupational or take-home pathway for children's pesticide exposures.[7,10] A later Washington State study found a strong association between organophosphorus (OP) pesticides in dust from farm-worker's vehicles and residences, providing additional evidence for this exposure pathway.[13] A number of studies have also documented children's exposure due to spray drift following nearby applications of OP pesticides.[1,9,10,16]

Two studies have used biological monitoring to evaluate OP pesticide exposures in farming communities in Central America. A 1995 study collected urine samples and information on pesticide use for 103 households in El Salvador,[17] while a similar study in 1999 focused on six families in Nicaragua.[18] In northwest Nicaragua, the location of this study, approximately half of the economically active population works in agriculture; of those, 69% are small, independent farmers. Dangerous practices such as the use of inferior equipment, the lack of proper protective clothing, and the failure to adopt slower, non-chemical pest control methods are factors that contribute to occupational exposures.[19]

Rural agricultural families have direct contact with pesticides because they are often stored inside one-room homes, and pesticide containers are often reused for water or food.[19] Also, many rural Nicaraguans have homes that are open to the elements, with outside kitchens and dirt floors, thus making them more vulnerable to exposure through spray drift. Because of the warm climate and high humidity, both adults and children wear minimal clothing, and often walk barefoot inside and outside the house, thus increasing the opportunity for pesticide contact and dermal absorption.

The purpose of this study was to assess exposures to two OP pesticides—chlorpyrifos and diazinon—for pesticide applicators and their children. Metabolites specific to these pesticides were measured in the urines of study participants to determine exposure levels, and to evaluate exposure pathways under these conditions.

METHODS

Study Design

This study was cross-sectional, with multiple-day sampling. The study population included farm workers and children in the regions surrounding León and Chinandega in northwest Nicaragua. One child, aged 2–12, residing with each applicator was sampled. The farmers of León worked on small family-owned farms and used chlorpyrifos on their corn crops. The farm workers in Chinandega were employees of two large banana plantations who sprayed diazinon around the perimeter of the plantation blocks.

Recruitment Procedures

Initial contact among the small farmers was based on a list of 40 farmers who participated in a previous study by researchers at the Universidad Nacional Autónoma de Nicaragua, León (UNAN-León). We also contacted the Asociación de Trabajadores del Campo (Farmworker's Association) and the Instituto de Tecnología Agropecuaria (Fish and Agriculture Technology Institute) and were given information regarding community leaders in chlorpyrifos-using communities. The farmers were visited three to four times before the sampling began in order to explain the study and to confirm the application date and the exact time the farmers planned to apply chlorpyrifos. The recruitment goal was ten, but only seven small-farmer families were recruited. Other families consented to participate but were not sampled because their application schedules changed and the families were unable to communicate the changes to the research team. Only one of the families had electricity or telephone service. On the first day of sampling, the study was explained in detail and the oral assent form was read to the participants.

Contact with banana plantation administrators was initiated via a previous UNAN–León collaborator. Ten banana plantation workers and their families, six from Plantation 1 and four from Plantation 2, agreed to participate. In most cases, the child was the son or daughter of the applicator, but in some cases, the child was a grandchild, nephew, niece, or stepchild.

Ethical Considerations

The Human Subjects Committee at the University of Washington (Seattle, WA), and the Ethics Committee at the Universidad Nacional Autónoma de Nicaragua, (León, Nicaragua) approved the study. The study and its potential benefits and risks were explained to all study participants. Participants were not obligated to join the study and were free to drop out at any time. Participants were compensated monetarily for the inconvenience and their time and effort.

Field Sampling

Field sampling occurred from April 28 to June 20, 2003. The plantation portion of the study required two teams, each consisting of two research staff; one team traveled to the workers' houses to sample the children, while the other team collected samples at the workplace. All samples were collected in the presence of the researchers. The small-scale farm portion of the study required only one team, since these farmers applied the pesticides to fields located close to their homes. Researchers observed and recorded field activities, and collected relevant information from the applicators (e.g., where pesticides were purchased, age of the crop). No formal questionnaire was used.

Urine samples were collected from each pesticide applicator and one child residing with the applicator. A complete set of urine samples for the small-scale farmer families included four voids on the day of the application and three voids the day after the application. The sampling schedule was similar for plantation worker families, except only three urine samples were collected on the day of the application. Application occurred on one day only. Samples were immediately labeled and a tracking form was completed as samples were collected, which noted the details described on the label and any additional notes.

Urine Sample Analysis

Urine samples were stored in a cooler with frozen ice packs for transportation to the UNAN–León laboratory. Each urine sample was apportioned into several 15-mL conical tubes, stored at a temperature between –10°C and –20°C, and subsequently shipped with dry ice to the United States via express mail. The samples were analyzed for the specific metabolite of chlorpyrifos, 3,5,6-trichloro-2-pyridinol (TCPY), and the specific metabolite of diazinon, 2-isopropxy-4-methyl-pyrimidinol (IMPY), at the National Center for Environmental Health, Centers for Disease Control and Prevention (CDC), Atlanta, following the CDC's recently published method.[20] The limits of detection for TCPY and IMPY were 0.31 and 0.58 μg/L, respectively.

Data Analysis

Concentrations of TCPY and IMPY were log-normally distributed. Statistical analyses (descriptive statistics, linear regression analysis, and paired t-test) for the data were performed using SPSS® 12.0.

RESULTS

A total of 221 urine samples (107 from small-farm families and 114 from plantation families) were collected from 17 adults and 17 children: all of the appli-

TABLE 1 Urinary Concentrations of Chlorpyrifos Metabolite TCPY in Small-scale Farming Families

	No.	Arithmetic Mean (µg/L) ± SD*	Geometric Mean (µg/L) ± GSD*	Range (µg/L)	Percentile 25	Percentile 50	Percentile 75
Adult							
Pre-application	7	3.96 ± 8.1	0.76 ± 6.7	ND§–22	N/D	0.5	3.8
Hours post-application†							
2.5		21.0 ± 34.1	3.44 ± 10.4	ND–88	0.5	2.2	46.9
8.5	6	12.19 ± 8.2	8.31 ± 3.3	0.9–24	4.9	12.5	19.0
10	6	35.6 ± 54.0	18.1 ± 3.1	6.9–145	8.0	13.3	56.3
24	7	48.6 ± 49.2	23.5 ± 5.3	0.9–129	12.4	27.9	106
27	7	51.7 ± 58.8	25.8 ± 4.0	2.9–147	8.8	29.3	125
34	7	44.8 ± 46.8	17.7 ± 9.3	ND–142	11.6	35.6	51.7
Child							
Pre-application	7	3.06 ± 3.5	0.96 ± 6.7	ND–7.5	0.2	0.7	6.6
Hours post-application†							
2.5	7	6.97 ± 7.6	1.82 ± 9.5	ND–18	0.2	4.3	14.3
8.5	6	25.3 ± 49.3	2.99 ± 14.5	ND–125	0.2	5.2	43.1
10	7	3.32 ± 4.1	1.12 ± 6.3	ND–9.7	0.2	1.4	7.8
24	7	2.06 ± 2.9	0.63 ± 6.2	ND–7.8	0.2	0.5	4.0
27	7	3.39 ± 3.2	1.89 ± 4.0	ND–8.4	0.8	2.4	6.9
34	7	1.74 ± 2.4	0.91 ± 3.7	ND–6.9	0.4	0.9	2.3
Previous studies‡							
NHEXAS: adults	346	6.8 ± NR§	5.1 ± NR				
CDC: adults	832		1.5 ± NR				
MNCPES: children	261	9.2 ± 0.48	6.4 ± 1.1				
CDC: children	481	NR	2.88 ± NR				

*SD = standard deviation; GSD = geometric standard deviation.
†Actual sample collection times varied around the times listed.
‡NHEXAS = National Human Exposure Assessment Survey: Maryland[33]; CDC = Third National Report on Human Exposure to Environmental Chemicals, adults aged 20–59 years, children aged 6–11 years[34]; MNCPES = Minnesota Children's Pesticide Exposure Study, children aged 3–13 years.[35]
§ND = nondetectable (below the limit of detection); assigned one-half the limit of detection; NR = not reported.

cators were male; 10 of the children were female and 7 were male.

Small-scale Farm Field Conditions

All of the small-scale farmers applied chlorpyrifos to their fields. Four of the farmers took the pesticide from a sealed container labeled Chlorpyrifos Ethyl 48%. The three other farmers purchased the pesticide from another family in the study with a sealed labeled container and subsequently stored it in a Coke bottle. No chemical analysis was performed on the unlabeled pesticides to confirm their contents. Six of the seven families used 100 mL of formula per 20 L backpack, and one family used 62.5 mL per 20 L backpack. Numbers of 20-L backpacks used in the applications ranged from four to six.

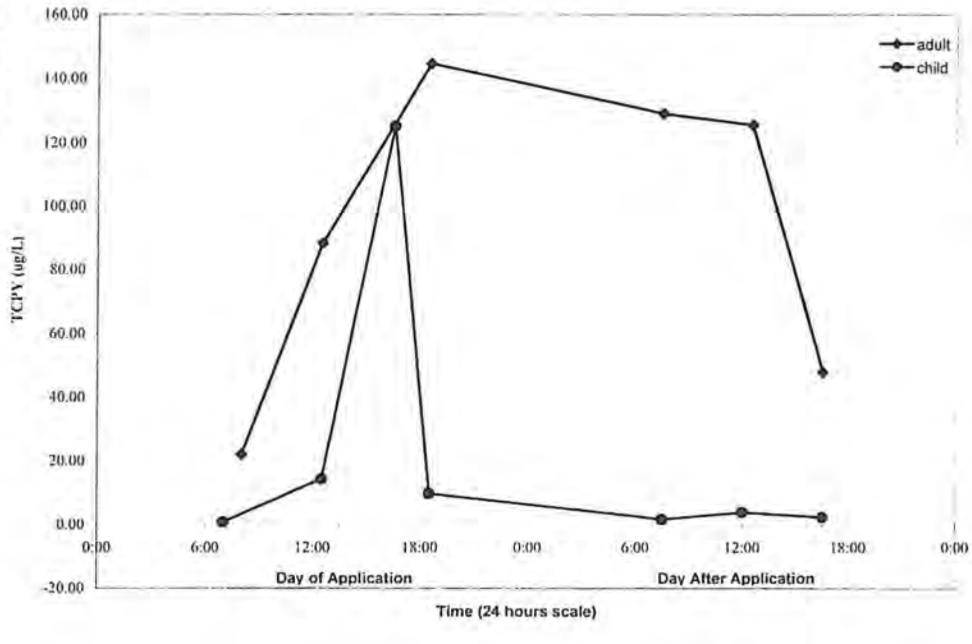
Chlorpyrifos was used to prepare the soil for sowing, or to spray the young plants. The farmers reported that they had not sprayed any OP pesticides for over a week. Applicators sometimes sprayed the pesticides against the wind, and personal protective equipment was generally not used. In all cases except one, application occurred in the morning after the first urine sample was taken. The farmer who applied in the afternoon was excluded from the analyses because the difference in the schedule complicated comparisons between participants.

Pesticide mixing took place in or near the household kitchen in most cases. Not all farmers applied pesticide to their own fields, as some of the applicators were employees of other farmers; in those cases, the pesticide was mixed in the employer's kitchen. Children were usually at school when the application occurred.

Urinary TCPY Levels among Small-scale Farmers and Their Children

Detectable levels of TCPY were found in 48 of 53 samples (91%) of small-scale farmers, and in 37 of 54 samples (69%) taken from their children (Table 1). Adult TCPY concentrations peaked 27 hours after application, with a geometric mean of 25.8 µg/L, a 30-fold increase from the pre-application level. This difference was statistically significant (paired *t*-test, $p < 0.01$). The highest TCPY concentration observed among the farmers was 147 µg/L. The geometric mean 34 hours post-application, the final sample collection period, was 20 times greater than the pre-application level. Child TCPY concentrations peaked 8.5 hours after application, with a geometric mean of 2.99 µg/L, a threefold

Figure 1—TCPY levels (µg/L) in urine samples of applicator and child in one small-scale farmer family. The child was playing outside during the chlorpyrifos application.



increase from the pre-application level. This difference was not significant ($p > 0.05$). The child with the highest level of TCPY, 125 µg/L, was a 9-year-old boy who was outside the home playing basketball during the chlorpyrifos application. Figure 1 illustrates the exposure profile for this family.

Linear regression was used to examine the associations between adult and child metabolite levels. The evening sample taken on the day of application showed a significant correlation (beta = 1.29; CI = 0.19–2.9; R^2 = 0.73; Pearson's r = 0.85; p = 0.03).

Plantation Field Conditions

Diazinon was applied in ornamental plants around the blocks of banana plants in order to avoid the propagation of pests from one block to another. Biological controls, such as beneficial insects, were used directly on banana plants at both plantations. Diazinon was sprayed approximately once a month in each block.

Both plantations used diazinon 60%: 2 L of the formulation were diluted in 480 L of water, and this mixture was transferred to 20-L backpacks. The pesticide formulation was measured by the supervisor in a warehouse on the plantation and then transported to the application site. The formulation was then mixed with water on site and the applicators were assigned an area to apply. After emptying a backpack, the worker had to walk back and fill up the backpack. Two of the workers at Plantation 1 did not actually apply the pesticide; one mixed the pesticide, and the other was a supervisor. However, both were in the field during diazinon applications. Eight 20-L backpacks were applied at Plantation 1 and 12 at Plantation 2 by each applicator. Plantation management reported that diazinon had not been sprayed for at least 15 days prior to sampling. Applications at Plantation 1 took place between 5:30–10:00 and 13:00–15:00, and at Plantation 2 from 6:00–10:00 to 13:00–15:00 hours.

Workers wore the following protective equipment: coveralls, shin guards, impermeable capes, gloves, boots, and hats, but no masks or respirators. Some protective equipment at Plantation 2 was in questionable condition. Researchers noticed that exposed clothes were wet after application. Two of the employees' families lived close to the plantation, but the remainder lived in a nearby city.

Urinary IMPY Concentrations among Plantation Workers and Their Children

The diazinon metabolite (IMPY) was found in 46 of 58 samples (79%) from workers, but in only 3 of 57 samples (5%) from their children. Table 2 summarizes urinary IMPY concentrations for the two plantations. We present descriptive statistics for the adults only, since so few of the children's samples were measurable. IMPY concentrations for workers at Plantation 2 were more than 100-fold higher than those of Plantation 1 workers. As can be seen in Figure 2, the highest IMPY concentrations for workers at Plantation 1 were reached two hours after the second diazinon application (geometric mean: 1.34 µg/L), whereas Figure 3 illustrates that the highest IMPY concentrations for Plantation 2 workers occurred 30 minutes after the second application (geometric mean: 168 µg/L).

Comparison of pre-application urinary IMPY concentrations with post-application concentrations yielded only one statistically significant difference: a decrease in mean IMPY concentration the day after

TABLE 2 Urinary Concentrations of Diazinon Metabolite IMPY in Banana Plantations Workers

	No.	Arithmetic Mean (μg/L) ± SD*	Geometric Mean (μg/L) ± GSD*	Range (μg/L)	Percentile 25	Percentile 50	Percentile 75
Plantation 1							
Pre-application	6	1.64 ± 1.6	0.94 ± 3.4	ND†–4.0	ND	1.2	3.1
Hours after morning applications							
1.5	6	2.72 ± 3.3	1.20 ± 4.4	ND–7.3	ND	1.0	6.6
Hours after afternoon applications							
2	6	4.21 ± 6.8	1.34 ± 5.4	ND–18	ND	1.1	8.1
15	5	1.25 ± 0.9	0.95 ± 2.4	0.4–2.4	0.4	1.5	2.0
20.5	5	1.77 ± 1.9	1.03 ± 3.5	0.4–4.9	ND	1.4	3.5
25.5	6	1.55 ± 2.3	0.75 ± 3.4	0.4–6.2	ND	0.7	2.4
Plantation 2							
Pre-application	6	107 ± 47	99.4 ± 1.5	60.5–171	68	98	154
Hours after morning applications							
0.5	6	84.67 ± 96	57.7 ± 2.5	29.0–228	32	41	181
Hours after afternoon applications							
0.5	5	215 ± 153	168 ± 2.4	52.4–412	177	198	370
15	6	127 ± 78	103 ± 2.3	33.5–198	48	139	195
20.5	6	71.1 ± 55	54.2 ± 2.4	19.9–141	24	62	127
23.5	3	52.4 ± 48	42.1 ± 2.1	22.6–112	23	37	97

*SD = standard deviation; GSD = geometric standard deviation.
†ND = nondetectable (below the limit of detection); assigned one-half the limit of detection.

application for workers at Plantation 2 ($p < 0.02$). It was not possible to examine a possible correlation between parent and child exposures in most cases, given the high frequency of samples below the limit of detection for workers' children. Linear regression was performed only on the midday samples, and no statistically significant relationship was found.

Urinary TCPY Concentrations among Plantation Workers and Their Children

We did not anticipate detecting TCPY in the urines of the banana plantation workers and their children, but found that 57 of 58 of the workers' samples (98%), and 45 of 56 of the child samples (79%) contained measurable TCPY concentrations. As shown in Table 3, TCPY concentrations ranged from nondetectable to 109 μg/L for adults and from nondetectable to 20.2 μg/L for children.

DISCUSSION

Small-scale Farmers and Their Children

In this study we found that exposures occurred among small-scale farmers and their children following chlorpyrifos applications on crops near the home. The steady increase in TCPY concentrations, peaking at 27 hours post-application for adults, is consistent with the pharmacokinetics of chlorpyrifos,[21] as is the continuing excretion of TCPY 34 hours post-application. In a study of structural pest control applicators using chlorpyrifos, a maximum concentration of TCPY urine levels occurred 18-24 hours after application.[22]

The peak exposure at 8.5 hours post-application for children in these families suggests that the children metabolize and excrete chlorpyrifos more rapidly than do their parents. It seems likely that the children's exposures were due in some cases to proximity to spraying, and that the activity of the children during the application time was an important factor in these exposures. For example, the child with the highest exposure played basketball outside his home close to the sprayed field (see Figure 2), whereas the child with the lowest exposure was inside his home with his mother during the application time.

It also seems likely that children's exposures were influenced more directly by occupational activities. The strong correlation observed between adult and child samples taken on the day of application in the evening is supportive of a take-home pathway. Such para-occupational exposures may have resulted from household contamination during preparation of the spray mixture inside the home. A 1999 study in Nicaragua reported that the most highly exposed adults and children were in the same families, and that the applicators had stored the pesticide mixtures in their homes overnight.[18] In our study the preparation of spray mixture in or near the kitchen was a common occurrence. In the 1999 Nicaragua study estimates of

TABLE 3. Urinary Concentrations of Chlorpyrifos Metabolite TCPY in Banana Plantation Families

	No.	Arithmetic Mean (µg/L) ± SD*	Geometric Mean (µg/L) ± GSD*	Range (µg/L)	Percentile		
					25	50	75
Adult							
Day 1							
Morning	10	12.49 ± 11	8.43 ± 2.67	2.1–31.3	3.2	10.6	21.8
Midday	10	13.95 ± 24	4.63 ± 5.62	ND†–81.6	1.4	5.4	15.3
Late afternoon	10	22.42 ± 34	6.33 ± 7.09	0.2–108.7	1.3	8.2	36.6
Day 2							
Morning	9	12.57 ± 16	6.78 ± 3.25	1.7–50.5	2.1	4.9	18.4
Midday	9	10.18 ± 8.2	5.58 ± 4.78	ND–21.1	2.8	7.3	19.6
Late afternoon	10	10.35 ± 11	6.24± 3.15	0.7–35.6	3.6	6.7	15.4
Child							
Day 1							
Morning	10	3.67 ± 6.1	1.19 ± 5.5	ND–20.2	N/D	1.5	4.2
Midday	10	2.16 ± 2.8	1.02 ± 3.9	ND–9.1	0.3	1.1	3.4
Late Afternoon	9	3.37 ± 4.3	1.32 ± 5.2	ND–12.6	0.2	2.0	5.8
Day 2							
Morning	10	4.03 ± 5.3	2.08 ± 3.3	0.3–17.5	0.8	1.7	6.8
Midday	10	2.43 ± 3.9	0.68 ± 5.6	0.2–11.8	N/D	0.4	3.9
Late afternoon	7	4.51 ± 3.7	2.54 ± 4.3	ND–9.2	1.1	3.1	8.4
Previous studies‡							
NHEXAS: adults	346	6.8 ± NR†	5.1 ± NR				
CDC: adults	832	NR	1.53 ± NR				
MNCPES: children	261	9.2 ± 0.48	6.4 ± 1.1				
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*SD = standard deviation; GSD = geometric standard deviation.
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absorbed doses rather than TCPY urinary concentrations are reported, so direct comparison with our study is not possible. A 1995 study of farm families in El Salvador found an elevated odds ratio for living in a household whose head farmer had applied OP pesticides, indicating a take-home pathway as well.[17]

There are other possible explanations for the elevated TCPY concentrations in the children in our study, such as contamination of the water supply, contact with pesticide containers near the home, laundering of pesticide-contaminated clothing, or direct contact with a family member working with the pesticide. However, given the rapid appearance and subsequent decline of TCPY in children's urine following the applications, it seems most likely that many of these exposures were associated with the storage of application equipment and the preparation of spray mixtures inside the home. This is "take-home" exposure in the most literal sense.

Plantation Workers and Their Children

Plantation workers and their children presented a very different exposure profile. The most striking finding from this portion of the study was the large difference in diazinon exposure levels at the two plantations. At both plantations, peak IMPY levels were reached soon after the second diazinon application (1.4 and 168 µg/L for Plantations 1 and 2, respectively).

It seems evident from the IMPY concentrations in workers that diazinon had been used previously at plantation 2 (i.e., a geometric mean of 99 µg/L in pre-application samples), and that this prior exposure contributed to the IMPY concentrations observed during the study. Greater amounts of diazinon were applied by workers at Plantation 2: 12 backpacks per worker, as compared with eight backpacks per worker at Plantation 1. The difference in exposures across the two plantations was also likely the result of differences in hygienic facilities (which were superior in Plantation 1), the use of inadequate protective equipment, and inappropriate application methods at Plantation 2.

Only 5% of the samples from children of plantation workers from either plantation had detectable levels of IMPY, indicating that the take-home pathway was not a significant source of exposure during the study period. We speculate that the presence of TCPY in the urines of both plantation workers and their children was due to contact with chlorpyrifos-impregnated bags used commonly on banana plantations to protect the fruit from insects. These bags are removed from the banana trees at harvest, commonly litter the plantation, and are sometimes taken home by the workers. In one home we

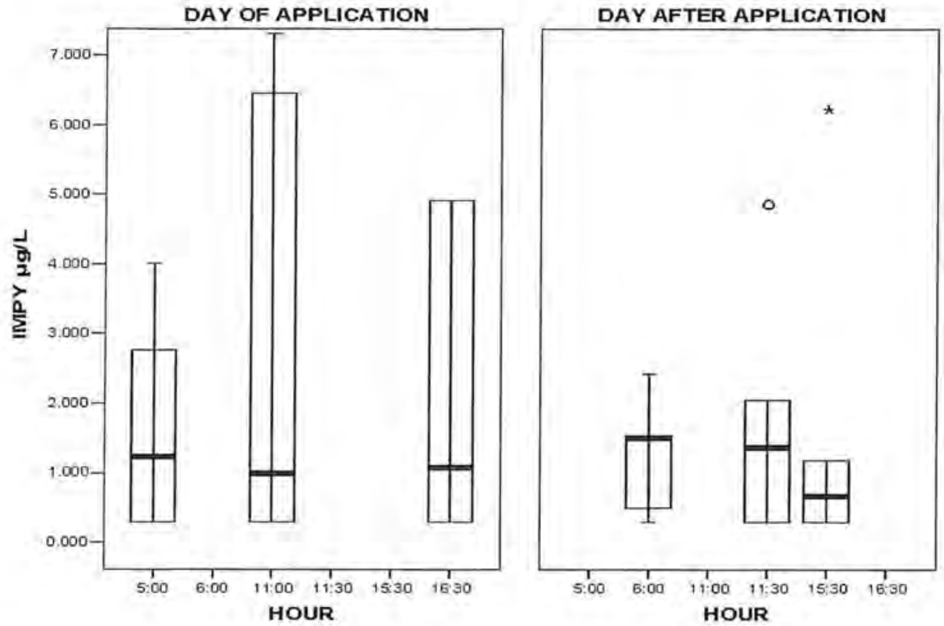


Figure 2—Boxplot of IMPY levels (µg/L) in Plantation 1 workers. From the bottom to the top, the box lines in the figure represent 25th percentile, median, 75th and 90th percentiles, respectively. Diazinon applications took place between 5:30–10:00 and 13:00–15:00 hours on the day of application. Notice the difference in IMPY concentration scales between Figure 2 and Figure 3.

observed these bags stuffed into wall cracks to serve as insulation.

Comparison of Biological Exposure Levels with Other Studies

The comparison of our biological monitoring results for chlorpyrifos with previous studies is problematic because OP pesticide exposures have most often been measured via blood cholinesterase activity or dialkylphosphate metabolite concentrations.[7,10,23–32] However, several studies have reported TCPY and IMPY concentrations, and are discussed here.

As shown in Table 1, TCPY levels in adult farmers in this study were substantially higher than adult TCPY levels reported in the United States.[33,34] This difference is not surprising, as the participants in this study were occupationally exposed. The peak TCPY level in children of small-scale farmers (3.0 µg/L geometric mean) was about half the geometric mean reported in a probability-based sample of 102 children in Minnesota,[35] and similar to levels reported for children aged 6–11 in the U.S. population.[34]

Reported concentrations of IMPY in the U.S. population to date have been low: levels were detected in only 29% of the samples tested, and in only 22% of the children tested.[36] Our findings for plantation-worker children were similar. We have not identified any previous occupational exposure studies that have reported IMPY concentrations in urine related to diazinon use.

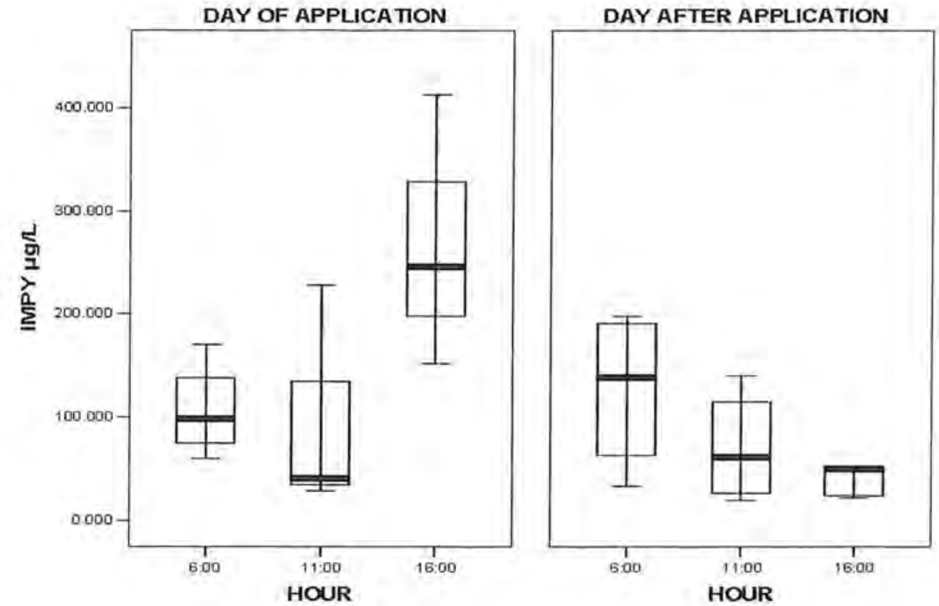
Measurable TCPY concentrations were found in 98% of the plantation workers' samples, and in 79% of the samples taken from their children. The range of geometric means of TCPY levels for banana plantation workers (Table 3) was lower than that for the small-scale farmers (Table 1). Workers' TCPY levels peaked with a geometric mean of 6.8 µg/L, which was 1.3 times higher than that found in a study of U.S. residents in Maryland,[33] and 4 times higher than values for U.S. adults.[34] The geometric mean for TCPY concentrations ranged from 0.7 to 2.5 µg/L in the children of the banana plantation workers, lower than levels reported in the U.S. studies.[34,35] No study has investigated the levels of chlorpyrifos in the general population in Nicaragua; thus it is not possible to compare the study results with resi;ts fpr the general Nicaragua population.

Study Limitations

There are two important limitations of this study. First, families were not approached randomly; thus a selection bias may exist. The small-scale farming families were recruited through recommendations from other farmers and agricultural experts in the region, and were considered by researchers to be representative of agricultural families in northwest Nicaragua. Recruitment of banana plantation workers was challenging due to past legal troubles in the industry related to the use of the soil fumigant di-bromo-chloro-propane (DBCP) and its effects on human fertility. It is possible that the plantations that agreed to participate were not representative plantations in Nicaragua. In addition, the applicators who participated in the study were selected by the plantation administrators.

Second, urinary metabolite levels were not normalized for creatinine, since the use of creatinine concentration as an adjustment factor may falsely elevate metabolite concentrations in children's urine samples.[37] Additionally, only spot urine samples were col-

Figure 3—Boxplot of IMPY levels (µg/L) in Plantation 2 workers. From the bottom to the top, the box lines in the figure represent 25th percentile, median, 75th and 90th percentiles, respectively. Diazinon applications took place between 6:00–10:00 and 13:00–15:00 hours on the day of application. Notice the difference in IMPY concentration scales between Figure 2 and Figure 3.



lected from participants; field conditions in Nicaragua make total urine collections impractical at this time.

CONCLUSIONS

This study provides evidence that children's exposure to chlorpyrifos is an issue that should be addressed in both small-scale farming families and banana plantation worker families. Proximity to spraying and the storage and preparation of chemicals in the home appear to have been the predominant factors responsible for exposures among small-scale farm children. There was no indication of para-occupational exposure to diazinon among children of banana plantation workers, but these children were exposed to chlorpyrifos. Diazinon exposures varied greatly between Plantations 1 and 2, illustrating the importance of applicator training and protective equipment. These findings support the need for more systematic exposure studies in farming populations in Nicaragua, and interventions to reduce exposures where appropriate. We provide the following recommendations based on this study:

1. Children's activities should be monitored during and after nearby pesticide applications to reduce potential exposures.
2. Pesticides should not be stored inside the home, and spray mixtures should not be prepared inside the home, and particularly not in the kitchen area.
3. Good occupational hygiene practices should be followed at banana plantations and at other sites where agricultural workers are asked to handle pesticides.
4. Plastic bags used for insect protection at banana plantations should be disposed of properly at the worksite, and should not be taken home or used for other purposes.

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