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Organophosphate Pesticide Exposure in School-Aged Children Living in Rice and Aquacultural Farming Regions of Thailand

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Abstract

Organophosphate pesticides (OPs) are widely used in agricultural sectors in Thailand. Previous studies have documented that children residing in agricultural areas have higher exposure to OPs than children living in other residential areas. The objective of this study was to quantify urinary biomarkers of OP exposure and determine the environmental conditions and activities that predict their levels among children living in Central Thailand farming regions. In October 2011, 53 6–8-year-old participants were recruited from Pathum Thani Province, Thailand. Twenty-four lived in rice farming communities at Khlong Luang District where OPs are the pesticides used frequently. Twenty-nine participants, living in aquacultural farming communities at Lum Luk Ka District where OPs are not used, were recruited to serve as controls for pathways of exposure (e.g., residential, dietary) other than occupational/paraoccupational exposures encountered in rice farming. Household environments and participants' activities were assessed using a parental structured interview. Urine samples (first morning voids) were collected from participants for OP urinary metabolite (i.e., dialkylphosphates [DAPs] and 3,5,6-trichloro-2-pyridinol [TCPy]) measurements. The levels of most urinary OP metabolites were significantly higher in participants who lived in a rice farming community than those who lived in an aquacultural farming community ($P < .05$). The results from linear regression analysis revealed that the frequency of OP application on rice farms (}.DAP: $P = .001$; TCPy: $P = .001$) and living in a rice farming community (}.DAP: $P = .009$; TCPy: $P < .001$) were significant predictors of urinary DAP metabolite levels in participants. Increasing TCPy levels were significantly related to proximity to rice farm ($P = .03$), being with parent while working on a farm ($P = .02$), playing on a farm ($P = .03$), and the presence of observable dirt accumulated on the child's body ($P = .02$). In conclusion, OP metabolite levels among children who live in rice farming communities were strongly influenced by farming activity, household environments, and child behaviors, suggesting that these are the primary pathways in which children living in these agricultural communities in Thailand were exposed to OPs.

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Keywords

Activity; children; dialkylphosphates (DAPs); environment; organophosphate pesticides (OPs); 3,5,6-trichloro-2-pyridinol (TCPy)

INTRODUCTION

The agricultural sector in Thailand constitutes 12.2% of its gross domestic product.[1] Rice is a major crop that can be cultivated throughout the year and exported, earning approximately 6,500 million USD (approximately 196,000 million baht).[2] The use of a variety of agrochemicals have increased rice yields. Chlorpyrifos, a commonly used organophosphate pesticide (OP), was the most imported insecticide and has been used widely in Thailand to control various pests for several crops, such as vegetables, rice, and flowers.[3] OPs are known neurotoxicants through their function as cholinesterase inhibitors.[4] Children are more vulnerable to pesticide toxicity than adults because they are still developing. The primary adverse health effects associated with OP exposure in children are neurodevelopmental and neurobehavioral deficits.[5–7]

Exposure to pesticides, especially OPs, among children residing in agricultural areas is a rising concern in Thailand and elsewhere. OPs can drift from the application area to household environments and deposit in the dust on surfaces including floors where children are playing.[8] Parents who are farmers can transfer OPs to children living in the same houses by take-home (paraoccupational) exposure.[9] Mouthing behavior can lead to increased OP intake in young children.[10] Hence, children living in agricultural areas tend to have a higher probability of pesticide exposures than those who do not.

In order to assess OP exposure in children, urinary metabolites (i.e., class-specific dialkylphosphate [DAP] or pesticide-specific metabolites such as 3,5,6-trichloro-2-pyridinol [TCPy], metabolite of chlorpyrifos) are typically quantified.[11] TCPy was measured in the urine of school-aged children in northern Thailand and was found in samples of those residing in agricultural areas.[12] Petchuay et al. reported that children residing near agricultural areas in southern Thailand where OP use is widespread had higher DAP levels than children from other areas.[13]

In Khlong 7 Subdistrict, Pathum Thani Province, where our study was conducted, rice is a major crop and can be cultivated at least twice annually.[14] Chlorpyrifos is used with high intensity in this area, so measurement of DAPs and TCPy were important exposure measures in our study. Although there have been several biological monitoring studies among children in Thailand, only a few studies have explored factors predicting levels of OP exposure in children; therefore, this was an important element of our study.[15] This study aims to enhance the understanding of the relation between children's environment and activities with urinary OP metabolite levels in children living in rice farming communities in Central Thailand where OP use, especially chlorpyrifos, is high and year round.

METHODS

Study Areas and Participants

A cross-sectional study was conducted in October 2011, at high pesticide use period for rice cultivation and low pesticide use period for aquacultural farming. Sampling occurred within 24 hours after the last pesticide applications.

A total of 53 child participants, 6–8 years old, were recruited from Pathum Thani Province, Thailand. Twenty-four participants lived in rice farming communities at Khlong 7, Khlong Luang District, where OPs were applied in paddy fields throughout the year. Twenty-nine participants lived in aquacultural farming communities in Lum Sai, Lum Luk Ka District, where OPs were typically not used. This group of children served as the control group with no paraoccupational or occupational exposures, although their dietary and residential exposures to pesticides were believed to be similar to the other children.

About a month before sample collection, we arranged a meeting with parents and children to introduce them to the research project. Parents were given an informed consent form explaining our research plan and procedures. Children also provided their assent to participate in the study. The research protocol, including consent and assent forms, was reviewed and approved by the institutional review boards of Rutgers University (formerly UMDNJ) Robert Wood Johnson Medical School and Chulalongkorn University.

Questionnaires

Environmental conditions and activities of participant children were evaluated via a structured questionnaire administered during home visits. The face-to-face interview with the child participant's parent was conducted by a trained examiner. The questionnaire (adapted from Petchuay et al.,[13]) was used to collect the following information: parental occupation, proximity to rice farms, floor cleaning frequency, residential pesticide use (and type of pesticide if used), indoor and outdoor child activities, and parentally observed child behaviors (e.g., mouthing behavior, hygiene behavior, etc.). Data collected about activities and behaviors of children participants included duration, frequency, and dichotomous outcomes (yes/no).

Urine Samples

First morning void urine samples were collected from participant children and transferred to screw cap polyethylene tubes with a unique identifying code. Then, the tubes were secured in zip top plastic bags and kept in an ice box during transportation to the laboratory. The urine samples were stored at −40°C in a freezer before shipping on dry ice for analyses. The sample analyses were performed under a collaborative agreement with the Research Institute for Health Sciences (RIHES), Chiang Mai University, Chiang Mai, Thailand, and the Department of Environmental Health, Rollins School of Public Health (RSPH), Emory University, Atlanta, Georgia, USA. All samples were analyzed concurrently with analytical calibration standards, blanks, and quality control materials using two previously published methods.[16,17]

For DAP analyses, which were performed at RIHES, the urine samples were saturated with salt and acidified then extracted with acetone:ethyl acetate. The extract was derivatized with pentafluorobenzyl bromide to form the pentafluorobenzyl phosphate esters of the DAPs. The DAPs were analyzed using gas chromatography–nitrogen phosphorus detection. This method was cross- validated with a mass spectrometry–based method and achieved international certification. The six common DAPs measured and their limits of detection (LODs in μg/L units) were dimethylphosphate (DMP; 2.5), diethylphosphate (DEP; 0.2), dimethylthiophosphate (DMTP; 0.2), dimethyldithiophosphate (DMDTP; 0.2), diethylthiophosphate (DETP; 0.1), and diethyldithiophosphate (DEDTP; 0.2). Relative recoveries ranged from 94% to 119%, whereas relative standard deviations (RSDs) ranged from 3.4% to 17%. The summed molar concentrations of DAPs (ΣDAP) were calculated, following the description provided in Panuwet et al.[12]

TCPy was measured using a minor modification of a method previously published.[17] Briefly, TCPy in urine was hydrolyzed to liberate its glucuronide and sulfate-bound conjugates. The hydrolysate was extracted using solid-phase extraction and analyzed by high-performance liquid chromatography– tandem mass spectrometry (HPLC-MS/MS) at the Analytical Exposure Science and Environmental Health Laboratory at RSPH, Emory University. Quantification was achieved using isotope dilution calibration and included quality control materials analyzed concurrently with unknown samples. The LOQ of TCPy was 0.25 μg/L, with a relative recovery indistinguishable from 100% and RSDs less than 10%. Demographic variables for all samples analyzed for both DAPs and TCPy were blinded to all analysts until after analysis.

Urinary Creatinine Measurement

Urinary creatinine concentrations were measured using an automated colorimetric method adapted from the Jaffe reaction[18] at Maharaj Nakorn Chiang Mai Hospital, Chiang Mai University, Thailand. The urinary creatinine levels were used to normalize the detectable metabolite concentrations to correct for dilution of urine. The adjusted concentrations were presented in micrograms of analyte per gram creatinine (μg/g Cr).

Absorbed Daily Dose (ADD) of Chlorpyrifos

For each child, the ADD value (μg/kg/day) for chlorpyrifos was calculated using the equation below, obtained from Curwin et al.[9]:

$$ADD\,(\mu\mathrm{g}/kg/day) = [\mathrm{C} \times \mathrm{C_n} \times CF \times \mathrm{R}_{mw}]\,/BW$$

C is the concentration of chlorpyrifos metabolite in urine per gram creatinine (μg/g Cr), and Cn is the calculated mass of creatinine excreted per day. To account for incomplete excretion of pesticides in urine, the correction factor (CF) of 1.4 as performed by Nolan et al.[19] in their study of children was applied. We recognize that this correction factor could account for incomplete excretion of an oral dose but does not account for a dermal dose of chlorpyrifos, particularly if dermal exposure was significant. However, we chose the Curwin et al. method as the best available. The ratio of chlorpyrifos and TCPy metabolite molecular weights (R_{mw} =1.77) was then divided by body weight (BW; kg). The ADD values were compared with the US Environmental Protection Agency (US EPA) acute and chronic population-adjusted doses (PADs), which are reference doses (RfD) with additional safety factors included to be protective of children.[20]

Statistical Analysis—SPSS version 16 (SPSS, Chicago, IL, USA) was used for data analysis. All data were tested for normality before appropriate statistical analyses were performed. Mean, standard deviation (SD), and frequency were reported for variables associated with participant demographics, characteristics, environments, and activities. Independent t test was used to compare the continuous data (e.g., age and income) between participant groups. Chi-square tests (χ^2) were used for comparison of categorical data between participant groups. The urinary metabolite concentrations below the LOD or limit of quantitation (LOQ) were assigned a value equal to LOD/√2 or LOQ/√2. Geometric means (GM) and ranges were reported for all urinary pesticide metabolite concentrations, including their molar summed concentrations.

For nonparametric statistics, Mann-Whitney U tests were used to compare the creatinine-adjusted concentrations of urinary OP metabolites between participant groups. In order to determine the association between age and urinary pesticide metabolites, Spearman's correlation coefficients were used. Linear regression, adjusting for age and creatinine concentration, was used to determine the relationship between participant's environment and urinary pesticide metabolite concentrations. Logarithmic transformations were used for the positive skewed concentrations of pesticide metabolites to reduce the variance in regression models.

RESULTS

Children's Environmental Conditions and Activities

Demographics of children participants are presented in Table 1. Of 53 enrolled participants, 31 were males and 22 were females. There were no significant differences observed between participants from rice farming communities and aquacultural farming communities in age, sex, body mass index (BMI), and parental education. Environmental conditions and activities of participants are shown in Table 2. All participants' parents from rice farming communities were rice farmers, whereas all of participants' parents from aquacultural farming communities were aquacultural farmers. The average family income was significantly greater for participants living in aquacultural farming communities relative to rice farming participants (aquacultural = 560 USD/month, rice = 380 USD/month; *t* test, $P < .05$).

Children's environmental conditions and activities, including proximity to rice farm, OP usage on farm, observable dirt on body, and playing on farm, were significantly different between participant groups. Most (75%) of the parents of rice farming children reported that they cleaned floors everyday with wet mops, a rate that was close to that reported by parents from aquacultural farming communities (86%). The majority (96%) of rice farmers whose children were participants reported using OPs on their farms, with the average frequency being four times/crop cycle (4 months), whereas none of the farmers in aquacultural farming communities had used OP pesticides on their aquatic farms. Participants from aquacultural farming communities (72.4%) had similar hand washing patterns as those from rice farming communities (54.2%) before consuming meals.

Children from rice farming communities were found to have higher frequencies of observable "dirt on the body" (yes/no variable) after outdoor play than those from aquacultural farming areas (83% and 55%, respectively; χ^2 test, $P = .04$). Participants from rice farming areas indicated that they had played on the farm, which was significantly higher than those from aquacultural farming areas (50% and 17%, respectively; χ^2 test, $P = .01$). There were no significant differences in the time spent in play (outdoors or indoors) or the time sitting or lying on floors between participants from rice farming and aquacultural farming areas (Mann- Whitney *U* test, $P > .05$). Similarly, no differences in hand-to-mouth behaviors between the two groups were observed. Younger participants had more observable object-to-mouth activities, more time playing on farms while their parents were working on the farm, and more observable dirt attached on their bodies than older participants; however, these findings were not significant (χ^2 test, $P > .05$).

Concentrations of Urinary Pesticide Metabolites

Concentrations of urinary OP metabolites from participants in this study are summarized in Table 3. More than one OP metabolite was detected in all participants irrespective of their demographic region or parental occupation. TCPy was detected in all samples from participants from rice farming communities but only in 82% of those from aquacultural farming communities. DETP and DEP were detected in 96% and 88% of samples tested for rice farming participants, respectively, but only in 66% and 55% of the samples obtained from aquacultural farming participants. Concentrations of non– creatinine-adjusted DEP and DETP had a positively significant correlation with ΣDAP (DEP: rho = .92, $P < .001$; DETP: rho = .69, $P <.001$), because they were the largest contributors to the summed value. Concentrations of non–creatinine-adjusted DEP and DETP were found to be significantly correlated with TCPy (DEP: rho = .49, $P < .001$; DETP: rho =.75, $P < .001$), suggesting that the primary OP to which participants were exposed was chlorpyrifos.

From Mann-Whitney *U* test, DEP and DETP concentrations in rice farming participants were significantly higher than participants from aquacultural farming areas (DEP: $P = .003$; DETP: $P = .002$). The ΣDAP concentrations in rice farming participants were significantly higher than aquacultural farming participants ($P = .008$). Similarly, TCPy concentrations in rice participants were significantly higher than in aquacultural farming participants (P = . 007).

Spearman's correlations suggested that age and creatinine-corrected ΣDAP concentrations were significantly correlated (rho = −.31, $P = .02$), but not with non–creatinine-adjusted concentrations. Similar results were observed for age and TCPy concentrations (creatinine-adjusted concentrations: rho = −.29, $P = .03$). reatinine levels had a positive significant correlation with age (Pearson's correlation: $r = .35$, $P = .01$).

Relationships Between Children's Environmental Conditions and Urinary Metabolites

Environmental conditions and activities of participants were used to analyze for their relationship to non–creatinine-adjusted urinary OP metabolite concentrations (log transformed) using a linear regression model that controlled for age and creatinine levels (Table 4). We found significant associations between ΣDAP concentrations and rice farmer family (P = .009) and frequency of OP use on farms (P = .001). Significant associations were found between log-transformed, non–creatinine-adjusted TCPy concentrations and being a member of a rice farming family (P < .001), proximity to rice farm (P = .03), parentally observed dirt on the body (P = .02), being with a parent on the rice farm (P = .02), playing on rice farms (P = .03), and frequency of OP application (P = .001). Analysis of some variables, such as "proximity to rice farm," returned results indistinguishable from "rice farming family member," because all rice farming participants lived close to the fields.

ADD

The GM of the TCPy ADD (range: 0.07–1.78 μg/kg/day; GM = 0.23 μg/kg/day) was significantly higher (Mann-Whitney test, P =.004) in rice farming participants than the participants from aquacultural farming areas (range: 0.01–0.61 μg/kg/day; GM = 0.10 μg/kg/day). All of the ADD estimates for rice farming participants and 82% of the aquacultural farming participants exceeded the US EPA's chronic PAD (0.03 μg/kg/day), but none of the participants had an ADD value exceeding the acute PAD (0.5 μg/kg/day) recommended by the US EPA.[20] Younger participants tended to have higher doses than older participants (Spearman's correlation: rho = −.246, P = .07).

DISCUSSION

The metabolites of chlorpyrifos (TCPy, DEP, and DETP) were the only metabolites that differed between rice and aquacultural farming children, suggesting that chlorpyrifos is widely used in rice farming in our study region and confirming previously reported results.[21]

Despite previously reported observations in northern Thailand demonstrating otherwise, [12] parental occupation as it relates to proximity to farms and child behaviors tended to have a large impact on pesticide exposures. Children of rice farmers lived in closer proximity to farms, tended to have more dirt on their bodies, and often played while parents worked on the farm. Conversely, children whose parents were aquacultural farmers spent less time outdoors, lived further from rice farms, and had less dirt on their bodies. All of these factors likely interplay to increase exposures in rice farmer children as compared with those whose parents worked in aquacultural farming.

Previous research revealed that the mouthing behavior in young children is a potential activity leading to nondietary ingestion.[22] Hand-to- mouth and object-to-mouth activities can lead to intake of OPs from contaminated soil or from surfaces that the child is playing around.[10] We hypothesized that younger participants in our study would have higher levels of OP metabolites than older participants. Although they had more opportunity to be exposed to OPs from contaminated environments than older children because they had been frequently observed with soil or dirt attached to their bodies after outdoor playing and they spent more time on the farm while their parents were working, we did not find an association between age and creatinine-corrected urinary metabolite levels.

Although participants from aquacultural farming areas had significantly lower OP metabolite concentrations than participants from rice areas, they still had measureable concentrations, suggesting exposure through a different pathway. Consumption of OP-contaminated foods can be another potential pathway of exposure to OPs among children irrespective of their proximity to farms using OPs.23 In 2011, the Thai Food and Drug Administration reported that 5.3% of fresh food samples available in local markets were contaminated with pesticide residues and exceeded the safety threshold.[24] In addition, OPs are commonly used for pest control in home gardens.[25]

Petchuay et al. reported DAP concentrations in children living near vegetable and rubber farms in Songkla Province, southern Thailand.[13] In the wet season, DAP concentrations of vegetable farm children were lower than concentrations detected in our participants from rice farms, except for DMTP. The DAP concentrations found in our study were also higher than the concentrations found in children living in vegetable and fruit farming communities in Nakhon-ratchasima Province, northeastern Thailand.[15] Concentrations of TCPy in school- aged children residing on vegetable, fruit, and ornamental farms in Chiang Mai, northern Thailand [12] were lower than the concentrations detected in our rice and aquacultural farming participants, even though the same methods were used for both studies.

Our data can also be compared with other countries to understand better the exposure situation in Thailand relative to more developed countries. The DAP concentrations in our study were lower than concentrations in German children aged 6–11 years in the GerES IV Pilot Study 2001–2002 when chlorpyrifos was still actively used in residential pest control.[26] Concentrations of metabolites of chlorpyrifos (TCPy, DEP, and DETP) were higher among our participants from rice farms than children of applicator families in Washington State, USA,8 and children aged 6–11 years in the US general population as measured in the US National Health and Nutrition Examination Survey (NHANES 1999– 2004).[27–29]

In order to extrapolate the population risk of participant children living in rice areas in our population, we calculated the ADD of all study participants.[30] All ADDs calculated in the rice farming participants exceeded the US EPA chronic PAD (0.03 μg/kg/day). Based on the pharmacokinetics of chlorpyrifos and our knowledge that crops are typically sprayed in the evening, we chose to collect first morning void as an estimate of exposure, recognizing that using this value probably reflects peak excretion of TCPy and thus may overestimate ADD.[11] Nonetheless, we believe that these ADD levels provide a reasonable estimate of daily chronic exposures, since the urinary concentrations appear to be related to dwelling location and behaviors that are relatively consistent over a season.

Despite the robust methods used in our study and our important findings, our study has limitations that are largely unavoidable and many are associated with financial limitations. First morning voids with creatinine-adjusted concentrations may overestimate concentrations compared with 24-hour urine samples.[31,32] Using creatinine correction for child populations may not be an appropriate way of correcting for urine dilution because of their endogenously lower creatinine concentrations.[21] The full 24- hour urine sample may be preferable to estimate the daily dose. The DAP metabolites may be derived from exposure to the parent chemical or the preformed metabolites, so we may have overestimated exposure to the biological active pesticides.[33] Preformed DAP and TCPy metabolites are potent sources of exposure, and both DAP and TCPy may be affected by transformed metabolites, not the parent compound chlorpyrifos. This study relied on questionnaire data or visual inspection to determine children's environmental conditions and activities, but the specific pathways of exposure were not directly measured. Some variables used during the statistical analysis to assess their predictive ability are parentally observed variables, which may be subjective and less accurate. However, because many of these variables are either dichotomous or categorical, the impact of this is limited. As a part of the project evaluating neurobehavioral effects among children living in agricultural communities, this study demonstrated the level of pesticide exposure. For further study, the behavioral health effects of exposure found in our population on children residing on farmland will be studied to help us better understand the implications of these exposures in Thai children.

CONCLUSION

The participants in this study had higher OP exposure than those reported in children residing in other areas in Thailand. The risk of pesticide exposure among participant children living near rice fields in Pathum Thani Province is undoubtedly a concern that requires public health attention, particularly given previous studies documenting neurobehavioral deficits among children with long-term OP exposure.[5–7]

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TABLE 1

Characteristics of Participants Classified by Residential Areas (Rice and Aquaculture)

Characteristic	Residential area		*P* value
	Rice farming communities (*n* = 24) Mean (*SD*) or *n* (%)	Aquacultural farming communities (*n* = 29) Mean (*SD*) or *n* (%)	
Age (year)	7.3 (0.7)	7.4 (0.8)	.76[a]
Sex			.27[b]
Male	16 (66.7%)	15 (51.7%)	
Female	8 (33.3%)	14 (48.3%)	
BMI	16.4 (3.6)	17.7 (4.4)	.27[a]
Parent's education (year)	7.7 (3.3)	8.9 (4.5)	.25[a]
Family income (THB/month)	11,500 (9,124)	16,800 (10,358)	.05[a]

Note. Parental education was reported as number of years each parent was educated in school.

[a] *t* test.

[b] Chi-square test.

TABLE 2

Environmental Conditions and Activities of Participants

Characteristic	Study area				Significance (χ^2 test)
	Rice area (*n* = 24)		Aquaculture area (*n* = 29)		
	n	**% or Mean ± *SD***	***n***	**% or Mean ± *SD***	
Rice farmer family	24	100	0	0	
Proximity from house to rice farm					
≤500 m	24	100	0	0	
>500 m	0	0	29	100	
Frequency of floor cleaning					
Not everyday	6	25	4	14	.29
Everyday	18	75	25	86	
OP used on farm	23	96	0	0	<.001**
Average frequency		1 time/month		Never used	<.001**
Hand washing	13	54	21	72	.198
Playing duration (hour/day)					
Outdoor	24	3.5 ± 2.2	29	2.6 ± 1.5	.21[a]
Indoor	24	6.5 ± 3.5	29	6.9 ± 3.3	.63[a]
Sit/lay on floor (hour/day)	23	2.9 ± 2.5	20	2.9 ± 3.4	.33[a]
Hand-to-mouth	7	29	15	52	.076
Object-to-mouth	14	58	15	52	.730
Dirt on body	20	83	16	55	.041*
Playing on farm	12	50	5	17	.014*

[a]Mann-Whitney *U* test.

*Significant level at *P* < .05.

**Significant level at *P* < .01.

TABLE 3

Major OP Metabolites Among Children Participants From Rice and Aquaculture Areas

Pesticide urinary metabolites	LOD/LOQ (µg/L)	Rice farming communities					Aquacultural farming communities					*P* value (Mann-Whitney *U* test)
		Detection (%)	Creatinine unadjusted (µg/L)		Creatinine adjusted (µg/g creatinine)		Detection (%)	Creatinine unadjusted (µg/L)		Creatinine adjusted (µg/g creatinine)		
			Range	GM	Range	GM		Range	GM	Range	GM	
TCPY	0.25	100%	0.6-22	4.6	1.90–55	6.0	82%	<LOD–10	1.5	<LOD–18	2.6	.007**
DMP	2.50	54%	<LOD–55	3.3	<LOD–82	4.3	27%	<LOD–13	2.1	<LOD–21	3.3	.88
DMTP	0.20	35%	<LOD–214	0.5	<LOD–284	0.6	48%	<LOD–17	0.4	<LOD–19	0.6	.87
DMDTP	0.20	20%	<LOD–1.9	0.2	<LOD–2.6	0.2	10%	<LOD–1.3	0.2	<LOD–2	0.2	.73
DEP	0.20	87%	<LOD–21	1.7	<LOD–33	2.3	55%	<LOD–5.2	0.3	<LOD–18	0.5	.003**
DETP	0.10	95%	<LOD–71	1.2	<LOD–74	1.7	65%	<LOD–14	0.2	<LOD–21	0.4	.002**
DEDTP	0.20	23%	<LOD–0.7	0.2	<LOD–1.8	0.2	7.1%	LOD–1.2	0.2	<LOD–0.9	0.2	.55
ΣDAP			26–2383[a]	210[a]	40–3165[b]	270[b]		20–375[a]	62[a]	15–1290[b]	101[b]	.008**
ADD[c]					0.07–1.78	0.23				0.01–0.61	0.10	.004**

[a] Reported in nmol/L.

[b] Reported in µmol/g creatinine.

[c] Reported in µg/kg/day.

** Significant level at $P < .01$. Mann-Whitney *U* test was performed between two groups, using creatinine-adjusted concentrations.

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TABLE 4

Results of Linear Regression Analysis of Levels of Exposure (Log-Transformed Creatinine-Unadjusted Concentrations, Controlled for Age and Creatinine)

Predictor	ΣDAP			TCPy		
	β	*t*	*P*	β	*t*	*P*
Frequency of OPs used on farm	0.444	3.591	.001**	0.416	3.824	.001**
Being a member of a rice farming family	0.361	2.734	.009**	0.451	3.805	<.001**
Proximity to rice farm	0.182	1.313	.195	0.274	2.150	.037*
Being with parent on rice farm	0.125	0.886	.38	0.304	2.403	.020*
Playing on rice farm	0.145	1.029	.309	0.273	2.127	.039*
Parentally observed dirt on body	0.017	0.122	.903	0.287	2.291	.026*
Frequency of floor cleaning	0.175	1.191	.239	–0.080	–0.563	.576
Washing hands before eating	0.007	0.048	.962	0.192	1.442	.156
Playing indoor	0.152	1.089	.282	0.124	0.935	.355
Playing outdoor	–0.011	–0.078	.938	0.027	0.203	.840
Frequency of finger-to-mouth	–0.112	–0.800	.428	–0.163	–1.250	.218
Frequency of object-to-mouth	–0.015	–0.109	.914	0.128	0.966	.339

*Significant level at $P < .05$.

**Significant level at $P < .01$.