Chapter 2
Conclusions

2.1 Overview

The CTEPP study examined the aggregate exposures of 257 preschool children to pollutants commonly found in their everyday environments. This study was conducted in six counties each in North Carolina (NC) and Ohio (OH) which are in two different geographical locations – the Southeast and the Midwest – of the United States. The overall goals of this study were (1) to measure the concentrations of the target pollutants in multimedia samples collected at the homes and at day care centers of 257 preschool children in six NC counties and six OH counties, (2) to determine the distributions of child characteristics, activities, and locations that contributed to their exposures, (3) to estimate the aggregate exposures of the preschool children to these pollutants that they may encounter in their everyday environments, and (4) to apportion the routes of exposure. Participants were recruited randomly from selected homes and child day care centers. Monitoring was performed over a 48-h period at the children's homes and/or day care centers. Environmental (air, dust, and soil) and personal (hand wipes, diet, water, urine) samples were collected. In addition, surface wipe samples including hard floor wipes, food preparation, and transferable residue (PUF) samples were collected from homes that had recent pesticide applications. The samples were analyzed by gas chromatography/mass spectrometry (GC/MS) for over 50 pollutants from such chemical classes as the organophosphate (OP) pesticides, organochlorine (OC) pesticides, pyrethroid pesticides, acid herbicides, polycyclic aromatic hydrocarbons (PAHs), phthalates, phenols, polychlorinated biphenyls (PCBs), and the triazine pesticide atrazine. The pollutants were selected because they had been commonly detected in the past in indoor and outdoor environments and/or were potentially carcinogenic, mutagenic, or endocrine disrupting chemicals in humans.

The study showed that the participating NC and OH preschool children were potentially exposed at their homes and day care centers to low levels of many of these pollutants from several sources. In addition, these children were potentially exposed/dosed at low levels to some of these pollutants through several pathways and routes. The conclusions derived from the study apply only to the children and their primary caregivers in NC and OH who participated in this study and cannot be generalized to all preschool children in either state. Therefore, the comparisons between results from NC and OH discussed below apply only to the results for children in the selected NC and OH counties. In addition, this data report has only discussed the potential exposures and potential absorbed doses of these preschool children and their primary caregivers to pollutants in these environments, *not* possible health effects associated with these exposures.

2.2 Goal 1

The CTEPP study's first goal was to measure the concentrations of the target pollutants in multimedia samples collected at the homes and day care centers of 257 preschool children in six NC and six OH counties.

2.2.1 Multimedia Sources of Potential Exposure

Many of the pollutants were detected in several environmental, personal, and biological media at the homes and day care centers of the participating NC and OH children. Pollutants that were detected in 50% or more of the samples in four or more types of environmental or personal media were regarded as "frequently detected" pollutants. For both NC and OH portions of the study, frequently detected pollutants included the following:

- **OP pesticides and metabolite**: chlorpyrifos, diazinon, and 3,5,6-TCP,
- **OC pesticides**: *alpha*-chlordane and *gamma*-chlordane**,**
- **Pyrethroid pesticides:** *cis*-permethrin and *trans*-permethrin,
- **PAHs**: benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, indeno[1,2,3-*cd*]pyrene,
- **Phthalates**: benzylbutylphthalate and di-*n*-butylphthalate, and
- **Phenols**: bisphenol-A and pentachlorophenol.

In addition, PCB 52 and IMP (the metabolite of diazinon) were classified as "frequently detected" pollutants within the OH portion of the study. PCB 52 was detected in more than 50% of samples in four types of media in OH but in only two types of media in NC. IMP was analyzed only in OH samples.

For pollutants that were frequently detected in indoor air, indoor floor dust, outdoor air, dermal wipe, and solid food samples, median concentrations within these media are given in Table 2.2.1 for both NC and OH. In both states, these median concentrations were generally higher for the indoor samples compared to the outdoor samples, although similar median values were observed in both indoor and outdoor environments for several PAHs, particularly in NC. Median PAH concentrations in indoor and outdoor air were slightly higher for NC air samples than for OH air samples. Both the NC and OH solid food samples contained only a few pollutants at median levels above the method detection limit (MDL). These pollutants were chlorpyrifos (0.17 and 0.18 ng/g), 3,5,6-TCP (2.3 and 1.9 ng/g), and bisphenol-A (4.1 and 3.5 ng/g), where the numbers in parentheses correspond to median levels in NC and OH solid food samples, respectively. It is of interest to note that median levels of 3,5,6-TCP were about 15 and 10 times higher than the chlorpyrifos levels in solid food samples from NC and OH, respectively. The break-down product of DDT, *p,p'*-DDE, was not classified as a frequently detected pollutant, but it was detected in greater than 50% of solid food samples. The median levels of *p,p'*-DDE were 0.16 and 0.18 ng/g, respectively, in NC and OH solid food samples. In dust samples, median concentrations of several PAHs were at least four times lower in homes and/or day care centers of NC children compared to OH. In dermal wipe samples, median concentrations of all PAHs were higher in OH than in NC. Lastly, median levels of bisphenol-A

were much higher in the dermal wipe samples in NC (5,900 ng/m^2) and OH (4,600 ng/m^2) compared to the other frequently detected pollutants (≤ 530 ng/m^2).

Table 2.2.1. Median Levels of Pollutants Frequently Detected in Air, Dust, Dermal Wipe, and Solid Food Samples Collected at the Homes and Day Care Centers of Preschool Children in NC and OH

	Indoor Air, ng/m^3		Dust, ng/g		Outdoor Air, ng/m^3		Dermal Wipe, ng/m^2		Solid Food, ng/g	
Pollutant/Metabolite	**NC**	**OH**	**NC**	**OH**	**NC**	**OH**	**NC**	**OH**	**NC**	**OH**
Chlorpyrifos	6.1	1.8	140	62	0.28	0.20	160	60	0.17	0.18
Diazinon	2.0	0.97	21	25	0.09	0.15	33	<[a]	<	<
3,5,6-TCP	1.8	0.65	92	42	0.23	0.21	130	78	2.6	1.9
IMP	–[b]	0.53	–	15	–	0.33	–	<	–	0.43[c]
alpha-Chlordane	0.84	0.23	24	11	0.09	0.09	34	<	<	<
gamma-Chlordane	1.5	0.34	36	13	0.13	0.10	42	<	<	<
cis-Permethrin	0.41	<	800	500	<	<	530	240	<	<
trans-Permethrin	0.27	<	730	390	<	<	300	190	<	<
Benz[*a*]anthracene	<	<	130	640	0.064	<	<	31	<	<
Benzo[*b*]fluoranthene	0.13	<	350	1700	0.19	<	<	79	<	<
Benzo[*k*]fluoranthene	<	<	110	620	0.064	<	<	40	<	<
Benzo[*ghi*]perylene	0.12	<	190	930	0.13	<	<	46	<	<
Benzo[*a*]pyrene	0.08	<	200	930	0.09	<	<	40	<	<
Benzo[*e*]pyrene	<	<	190	930	0.095	<	<	57	<	<
Chrysene	0.10	<	180	940	0.12	<	<	53	<	<
Indeno[1,2,3-*cd*]pyrene	0.09	<	180	880	0.095	<	<	41	<	<
Bisphenol-A	1.6	0.98	<	28	<	<	5900	4600	4.1	3.5

[a] "<" indicates that the median value falls below the MDL for the pollutant in this matrix.
[b] IMP was not measured in the NC samples.
[c] Reported value was underestimated because the recoveries of the matrix spike samples were less than 50%.

Although the two phthalates do not appear in Table 2.2.1, their median concentrations were high compared to other pollutants for two or more of the media types included in this table. The phthalate data were corrected for the background levels found in corresponding field blanks. Median concentrations for benzylbutylphthalate were 19,000 ng/g and 7,900 ng/m^2 in dust and dermal wipe samples, respectively, in homes and/or day care centers in NC. For di-*n*-butylphthalate, median concentrations were 6,800 ng/g and 9,000 ng/m^2 in the dust and dermal

wipe samples from NC. In OH, median concentrations of benzylbutylphthalate and di-*n*-butylphthalate were 19,000 and 6,400 ng/g in dust samples and were below the MDL within dermal wipe samples. Note that higher background levels were observed in OH dermal wipe samples compared to NC samples. These background median levels of the MDL were 6,400 and 8,000 ng/m^2 for benzylbutylphthalate, and 1,900 and 8,200 ng/m^2 for di-*n*-butylphthalate, in NC and OH dermal wipes, respectively.

Liquid food and soil media types were not included in Table 2.2.1, because measured concentrations of the frequently detected pollutants were typically low or below the MDL in these media. Only one pollutant, bisphenol-A, had median concentrations in liquid food samples which were above the MDL (0.46 ng/mL in NC and 0.49 ng/mL in OH). Generally, PAH concentrations in soil samples were lower than the corresponding dust samples. Median levels of the frequently detected PAHs ranged from 0.66 to 3.2 ng/g in NC soil and from 12 to 33 ng/g in OH soil. The median level of di-*n*-butylphthalate was 44 ng/g in OH soil, but below the MDL in NC soil.

Table 2.2.2 presents median concentrations of pollutants that were frequently detected in three types of surface samples that were collected after recent pesticide applications at homes in NC and OH (hard floor surface wipe, food preparation surface wipe, and transferable residues [PUF]). Median levels of chlorpyrifos and benzylbutylphthalate in the hard floor surface wipes, along with benzylbutylphthalate in transferable residues, were more than four times greater in samples collected from NC homes than those from OH homes. In addition, median levels of di-*n*-butylphthalate were slightly lower in all three surface sample types collected in NC homes than those from OH homes. In NC, median levels of the pyrethroid pesticides (*cis*- and *trans*-permethrin) ranged from 210 to 600 ng/m^2 in these surface wipes and transferable residue samples and were higher than those of the OP pesticides, while median levels of the pyrethroid pesticides ranged from 31 to 65 ng/m^2 for these sample types in OH homes.

In summary, several pollutants, including chlorpyrifos, 3,5,6-TCP, *cis*-permethrin, *trans*-permethrin, benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benz[*a*]anthracene, benzo[*b*]fluoranthene benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, indeno[1,2,3-*cd*]pyrene, benzylbutylphthalate, di-*n*-butylphthalate, and bisphenol-A, were frequently detected in several environmental media such as air, dust, and surface wipes, as well as in personal samples such as dermal wipes and foods, collected at the homes and day care centers of participating children in both states. Therefore, children could be potentially exposed to these pollutants in multiple environmental and personal media through different exposure routes.

Table 2.2.2. Median Levels of Pollutants Measured in Surface Samples Which Were Collected After Recent Pesticide Applications at Homes in NC and OH

Pollutant/Metabolite	Hard Floor Surface Wipe, ng/m^2		Food Prep. Surface Wipe, ng/m^2		Trans. Residue (PUF), ng/m^2	
	NC	OH	NC	OH	NC	OH
Chlorpyrifos	68	16	69	12	35	20
Diazinon	12	<[a]	16	<	33	7.3
cis-Permethrin	500	63	600	<	230	37
trans-Permethrin	400	65	260	<	210	31
Chrysene	25	47	6.4	<	18	16
Benzylbutylphthalate	29,000	6,100	2,100	2,000	28,000	5,400
Di-*n*-butylphthalate	5,000	7,200	3,400	5,500	5,100	7,500
Bisphenol-A	210	660	260	500	410	260

[a] "<" indicates that the median value falls below the MDL for the pollutant in this matrix.

2.2.2 Testing Important Hypotheses

One approach to addressing the first three of the seven hypotheses listed in Section 1.0 was to fit an analysis of variance model to the least squares mean of the log-transformed measurements of target pollutants in various environmental and personal sample media to determine whether these measurements differed significantly between 1) day care and home environments, 2) urban and rural environments, and 3) low-income and middle/high income environments. These measurements represented potential exposure levels for the participating children.

Comparisons between day care centers and home environments: When comparing environmental and personal sample measurements between day care centers and home environments in NC, highly significant differences ($p<0.01$) were frequently observed among the different pollutants and sample media, with higher levels frequently found in day care centers compared to homes. This was especially true for dust when pollutant concentrations were expressed as ng/m^2 (dust loadings). Loadings of diazinon, *alpha*-chlordane, *gamma*-chlordane, *cis*-permethrin, and *trans*-permethrin in dust were 10.0, 11.1, 11.1, 5.6 and 6.3 times higher, respectively, at day care centers than at homes in NC. Loadings of several PAHs (benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene) in dust ranged between 7.7 to 8.3 times higher at day care centers than at homes in NC. Loadings of benzylbutylphthalate and di-*n*-butylphthalate were both 10 times higher, and loadings of pentachlorophenol were 4.2 times higher, in dust at day care centers compared to homes in NC. In children's dermal wipe samples, bisphenol-A loadings were three times higher when collected

at day care centers versus homes in NC. However, highly significant differences between day care and home environments occurred less frequently when levels in floor dust were expressed in concentration units (ng/g). These results were partly due to the higher dust loadings measured in carpets at day care centers compared to homes in NC. The mean value of fine dust particle (<150μm) loadings in NC day care centers was more than twice that in NC homes.

Similar to NC, highly significant differences ($p<0.01$) were frequently observed among the different pollutants and sample media in OH, with higher levels frequently found in day care centers compared to homes, especially for dust when expressed as a loading. Loadings of chlorpyrifos, diazinon, 3,5,6-TCP, cyfluthrin, *cis*-permethrin, and *trans*-permethrin were 7.1, 5.9, 3.4, 4.3, 5.0, and 5.3 times higher, respectively, at day care centers than at homes in OH. Similarly, levels of PAHs (benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene) ranged between 5.6 and 6.7 times higher at day care centers than at homes in OH. Loadings of benzylbutylphthalate and di-*n*-butylphthalate were both 7.1 times higher in dust loadings at day care centers compared to homes in OH. In addition, levels of bisphenol-A and PCB 52 were 3.0 and 4.2 times higher, respectively, at day care centers than at homes in OH. However, like for NC, highly significant differences between OH day care and home environments occurred less frequently when levels in floor dust were expressed in concentration units (ng/g), partly due to the amounts of dust at OH day care centers being generally higher (approximately three times) than in OH homes.

Comparisons between urban and rural environments: Only the acid herbicide 2,4-D had dust concentrations (ng/g) which were highly significantly different ($p<0.01$) between urban and rural locations for NC, with concentrations being 3.2 times higher in urban settings compared to rural settings. In OH, there were several pollutants having concentrations in dust which were highly significantly different between urban and rural settings. Concentrations of PAHs (benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene) in OH dust samples ranged from 3.3 to 4.0 times higher in urban compared to rural environments. When PAH levels in dust were expressed as loadings (ng/m^2), the levels of benz[*a*]anthracene and chrysene were 3.2 and 3.0 times higher in urban than rural environments.

Comparisons between low-income and middle/high-income environments: In NC, several pollutants and sample media had highly statistically significant ($p<0.01$) differences occurring for children in the low-income compared to middle/high-income groups. Concentrations (ng/m^3) of diazinon, *cis*-permethrin, and *trans*-permethrin in indoor air samples were 3.6, 4.2, and 3.9 times higher, respectively, for low-income households than middle/high-income households. Loadings (ng/m^2) of diazinon, 3,5,6-TCP, *cis*-permethrin, and benzylbutylphthalate in NC dust samples were 6.3, 3.4, 3.2, and 4.8 times higher, respectively, for low-income households than for middle/high-income households. In contrast, concentrations of 2,4-D in dust samples (ng/g) were 4.5 times higher for middle/high-income households compared to low-income households.

In OH, loadings of chlorpyrifos in dust samples (ng/m^2) were 3.4 times higher in low-income households compared to middle/high-income households. In contrast, concentrations of

2,4-D in dust samples (ng/g) were 4.2 times higher in middle/high-income households than in low-income households.

Summary: As determined from analyses performed on environmental and personal sample media measurements, highly significant differences in floor dust loadings (ng/m^2) occurred between day care and home environments in both NC and OH for diazinon, the pyrethroid pesticides, the nine PAHs, and the two phthalates, with loadings at homes averaging less than one-third of the loadings observed in day care centers. These results were partly due to the higher levels of dust in the carpets at day care centers compared to homes in both states. NC preschool children were potentially exposed to higher levels of 2,4-D in dust samples (ng/g) within an urban location compared to a rural setting, suggesting that 2,4-D may have been used as a lawn herbicide for weed control more frequently in urban than in rural locations. OH children were potentially exposed to higher levels of several PAHs in dust (ng/g and ng/m^2) when in an urban location compared to a rural setting; PAH concentrations (ng/g) tended to be at least two times higher in urban dust samples than in rural dust samples in OH. Through indoor air, NC preschool children were potentially exposed to higher levels of diazinon, *cis*-permethrin, and *trans*-permethrin when in low-income environments compared to middle/high-income households. In addition, the NC preschool children were exposed to higher levels of diazinon, 3,5,6-TCP, *cis*-permethrin, and benzylbutylphthalate in dust (ng/m^2) when in low-income compared to middle/high-income households. However, concentrations of 2,4-D tended to be higher in dust samples (ng/g) from middle/high-income than from low-income households. In OH, levels of chlorpyrifos in dust (ng/m^2) were higher in low-income than in middle/high-income households, while concentrations of 2,4-D in dust samples were higher in middle/high-income households compared to low-income households.

2.3 Goal 2

The second goal of the CTEPP study was to determine the distributions of child characteristics, activities, and locations that contributed to their exposures. The factors that were considered important for determining the children's and their primary caregiver's potential exposures and potential absorbed doses to pollutants were the following:

- physical characteristics of the participant (body weight and hand surface area),
- children's activity patterns (frequency of placing toys and other objects in the mouth, pacifier use, teething, and frequency of washing hands),
- locations where children spent their time (indoor and outdoors at homes, at day care centers, or other locations)
- volume of liquid and weight of solid food consumed by the participant over a 24-h period.

These factors were used in the algorithms to estimate the children's exposures to pollutants at homes and/or day care centers through the inhalation and ingestion (dietary and indirect) routes of exposure. Exposures via the dermal route were not estimated for the children in this study.

2.4 Goal 3

The third goal of the CTEPP study was to estimate potential exposure level (ng/day) and potential absorbed dose (ng/kg/day) of the pollutants that the study participants may encounter in their everyday environments. ***Potential exposure*** (ng/day) is defined as the total amount of a pollutant that an individual comes in contact with over a 24-h period. ***Potential absorbed dose*** (ng/kg/day) is defined as the total dose that could be absorbed in the body by the three routes of exposure over a 24-h period, relative to the participant's body weight (kg). For each exposure route, potential absorbed dose was estimated by assuming a 50% absorption rate for all pollutants and participants. ***Aggregate potential exposure*** and ***aggregate potential absorbed* dose** were defined as the sums of the estimated potential exposure and potential absorbed dose, respectively, across all three exposure routes.

These estimates were made for selected pollutants via up to three routes of exposure (inhalation, dietary ingestion, and indirect ingestion). Then, for those pollutants having estimates available for all three exposure routes, aggregated potential exposure level and aggregated potential absorbed dose were calculated as the sum of the exposure/dose estimates across the three routes.

For each state, the following pollutants were considered for estimating potential exposure level and potential absorbed dose for the study participants:

- **OP pesticides/metabolite**: chlorpyrifos, diazinon, and 3,5,6-TCP,
- **OC pesticides**: *alpha*-chlordane, *gamma*-chlordane, *p,p'*-DDE, and heptachlor (NC only),
- **Pyrethroid pesticides**: cyfluthrin, *cis*-permethrin, and *trans*-permethrin,
- **Acid herbicide**: 2,4-D,
- **PAHs**: benz[*a*]anthracene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*ghi*]perylene, benzo[*a*]pyrene, benzo[*e*]pyrene, chrysene, dibenz[*a,h*]anthracene, and indeno[1,2,3-*cd*]pyrene,
- **Phthalates**: benzylbutylphthalate and di-*n*-butylphthalate,
- **Phenols**: bisphenol-A and pentachlorophenol, and
- **PCBs**: congeners 52, 95, and 101.

For most of these pollutants, potential exposure level and potential absorbed dose were estimated under a given exposure route for the study participants in a given state only when at least 45% of the samples collected in that state had detectable measurements for each media type entering into the calculation of the estimates.

For each state, aggregated potential exposure level and aggregated potential absorbed dose was estimated for the following eight pollutants (based on availability of exposure/dose estimates for each of the three exposure routes):

- **OP pesticides/metabolite**: chlorpyrifos, diazinon, and 3,5,6-TCP,
- **Pyrethroid pesticides**: *cis*-permethrin and *trans*-permethrin,
- **Acid herbicide**: 2,4-D,

- **Phthalate**: di-*n*-butylphthalate, and
- **Phenol**: bisphenol-A

2.4.1. Estimated Potential Exposure Levels for NC and OH Preschool Children

Potential exposure level (ng/day) was defined as the total amount of a pollutant that an individual comes in contact with over a 24-h period. The estimated potential exposure levels of the participating NC and OH preschool children were quantified by one or more routes of exposure for each of the pollutants mentioned above.

For the NC children, the estimated median potential exposure levels were highest for di-*n*-butylphthalate (1,800 ng/day) through the inhalation route of exposure, followed by lower levels of heptachlor (62 ng/day) and chlorpyrifos (47 ng/day). Estimated exposures to other pollutants via the inhalation route were less than 20 ng/day. When considering the dietary ingestion route, median potential exposure levels for NC children were highest for di-*n*-butylphthalate (39,000 ng/day), bisphenol-A (2,700 ng/day), and 3,5,6-TCP (1,200 ng/day), while exposures to other pollutants were less than 200 ng/day. When considering the indirect ingestion route, median potential exposure levels for NC children were highest for benzylbutylphthalate (920 ng/day) and di-*n*-butylphthalate (350 ng/day), *cis*-permethrin (48 ng/day), and *trans*-permethrin (35 ng/day) while estimated exposures to other pollutants were less than 10 ng/day.

For the OH children, the estimated median potential exposure levels were highest for di-*n*-butylphthalate (2,000 ng/day) through the inhalation route of exposure, followed by lower levels of pentachlorophenol (18 ng/day) and chlorpyrifos (15 ng/day). Estimated exposures to other pollutants via the inhalation route were less than 10 ng/day. When considering the dietary ingestion route, median potential exposure levels for OH children were highest for benzylbutylphthalate (9,400 ng/day), bisphenol-A (1,700 ng/day), and 3,5,6-TCP (860 ng/day), while exposures to other pollutants were less than 150 ng/day. When considering the indirect ingestion route, median potential exposure levels for OH children were highest for benzylbutylphthalate (630 ng/day) and di-*n*-butylphthalate (210 ng/day), while exposures to PAHs except for dibenz[*a,h*]anthracene (6.2 to 53 ng/day) and to *cis*- and *trans*-permethrin (18 and 12 ng/day) were each greater than 10 ng/day, and estimated exposures to other pollutants were less than 10 ng/day. These results suggest that participating children had the highest potential exposure levels to phthalates through all three routes of exposure.

2.4.2. Estimated Potential Absorbed Doses for NC and OH Preschool Children

Potential absorbed dose (ng/kg/day) was defined as the total amount that could be absorbed into the body over a 24-h period, relative to the child's body weight (kg). For each exposure route, potential absorbed dose was estimated under the assumption that all pollutants had a 50% absorption rate into the body for all exposure routes (17). The estimated potential absorbed doses of the NC and OH preschool children were quantified by one or more routes of exposure for each of the pollutants mentioned above.

For the NC children, estimated median potential absorbed doses were highest for di-*n*-butylphthalate (56 ng/kg/day) through the inhalation route of exposure, followed by much lower concentrations for heptachlor (1.7 ng/kg/day) and chlorpyrifos (1.4 ng/kg/day). When considering the dietary ingestion route, median potential absorbed doses for NC children were highest for di-*n*-butylphthalate(1,100 ng/kg/day), followed by bisphenol-A (74 ng/kg/day). Benzylbutylphthalate had the highest estimated median potential absorbed doses (26 ng/kg/day) under the indirect ingestion route of exposure, followed by di-*n*-butylphthalate (9.7 ng/kg/day).

For the OH children, estimated median potential absorbed doses were highest for di-*n*-butylphthalate (57 ng/kg/day) through the inhalation route of exposure, while all other pollutants had estimated median potential absorbed doses via the inhalation route of less than 0.6 ng/kg/day. When considering the dietary ingestion route, median potential absorbed doses for OH children were highest for benzylbutylphthalate (270 ng/kg/day), bisphenol-A (52 ng/kg/day) and 3,5,6-TCP (25 ng/kg/day), while median estimated potential absorbed doses through the indirect ingestion route were highest for benzylbutylphthalate (18 ng/kg/day), followed by di-*n*-butylphthalate (5.7 ng/kg/day). Like for potential exposure level, these results suggest that the preschool children had the highest potential absorbed doses to the phthalates through all three routes of exposure.

2.4.3. Estimated Aggregated Potential Exposure Levels for NC and OH Preschool Children

Aggregated potential exposure (ng/day) was defined as the sum of the estimated potential exposure levels across all three exposure routes – inhalation, direct ingestion and indirect ingestion – and was estimated for the eight pollutants mentioned earlier. Figure 2.4.1 presents median values of the aggregated potential exposure levels for the study participants.

NC children had the highest median aggregated potential exposure levels to di-*n*-butylphthalate (42,900 ng/day), followed by bisphenol-A (2,560 ng/day), and 3,5,6-TCP (1,230 ng/day), while the lowest median aggregated potential exposure level was observed for diazinon

Figure A

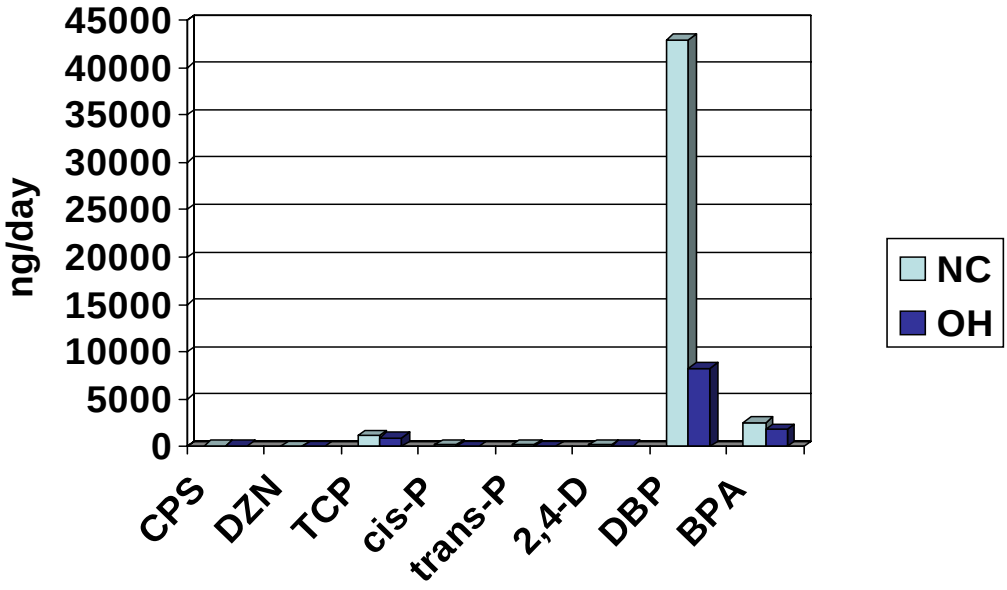

Figure B

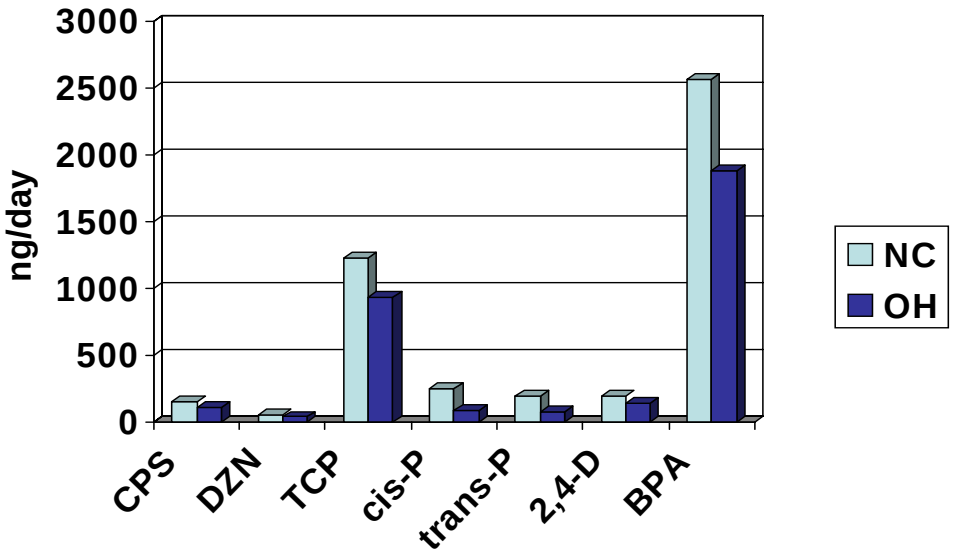

Figure 2.4.1 Estimated Median Aggregate Potential Exposure Levels of NC and OH Preschool Children to Eight Pollutants in Their Everyday Environments.

Legend: CPS = Chlorpyrifos; DZN = Diazinon; TCP = 3,5,6-Trichloro-2-pyridinol *Cis*-P and *Trans*-P = *Cis*- and *Trans*-Permethrin; 2,4-D = 2,4-Dichlorophenoxyacetic acid; DBP = Di-*n*-butylphthalate; BPA = Bisphenol-A

Note: Figures A and B are equivalent, except Figure B excludes DBP.

(51.6 ng/day). OH children had the highest median aggregate potential exposure levels to di-*n*-butylphthalate (8,310 ng/day), bisphenol-A (1,880 ng/day), and 3,5,6-TCP (930 ng/day), while the lowest median aggregate potential exposure level was observed for diazinon (38.6 ng/day). Thus, children in both states had the highest potential aggregate exposures to di-*n*-butylphthalate, bisphenol-A, and 3,5,6-TCP in their everyday environments. However, NC children had five times greater median aggregate potential exposure levels to di-*n*-butylphthalate than OH children.

2.4.4. Estimated Aggregated Potential Absorbed Doses for NC and OH Preschool Children

Aggregate potential absorbed dose (ng/kg/day) was defined as the sum of the estimated potential absorbed dose across all three exposure routes – inhalation, dietary ingestion, and nondietary ingestion – and was estimated for the eight pollutants mentioned earlier. Figure 2.4.2 presents median values of the aggregated potential absorbed doses for the study participants.

The NC and OH children had the highest median aggregated potential absorbed doses to di-*n*-butylphthalate (1,250 and 262 ng/kg/day) and bisphenol-A (71.4 and 60.8 ng/kg/day), respectively. Both the NC and OH children had the lowest median aggregated potential doses to diazinon (1.44 and 1.13 ng/kg/day), respectively.

The results show that both the NC and OH children had the highest estimated aggregated potential absorbed doses to di-*n*-butylphthalate in their everyday environments. However, the NC children had over four times greater median aggregated potential absorbed doses of di-*n*-butylphthalate than the OH children.

2.4.5 Urinary Biomarker Concentrations as a Indicator of Absorbed Dose

Several acid pollutants and metabolites were measured in urine samples collected over the 48-h sampling period from each study participant. Of these, 3,5,6-TCP, 2,4-D, and pentachlorophenol were used as indicators of aggregated potential absorbed doses. For NC children, median urinary concentrations were 5.3 ng/mL for 3,5,6-TCP (98% detected), 0.7 ng/mL for 2,4-D (94% detected), and 0.4 ng/mL for pentachlorophenol (89% detected). Similar median levels were observed for OH children: 5.1 ng/mL for 3,5,6-TCP (100% detected), 1.0 ng/mL for 2,4-D (98% detected), and 0.8 ng/mL for pentachlorophenol (99% detected).

In urine samples, NC and OH children had at least five times greater levels of 3,5,6-TCP compared to 2,4-D and pentachlorophenol. Overall, NC and OH children were exposed to low levels of these pollutants or their metabolites at their homes and/or day care centers over the 48-h sampling period.

2.4.6. Testing Important Hypothesis

Analyses of estimated potential exposure levels, potential absorbed doses, aggregated potential exposure levels, aggregated potential absorbed doses, and urinary concentrations of the participating children were performed to address the first three of the seven hypotheses listed in

Figure A

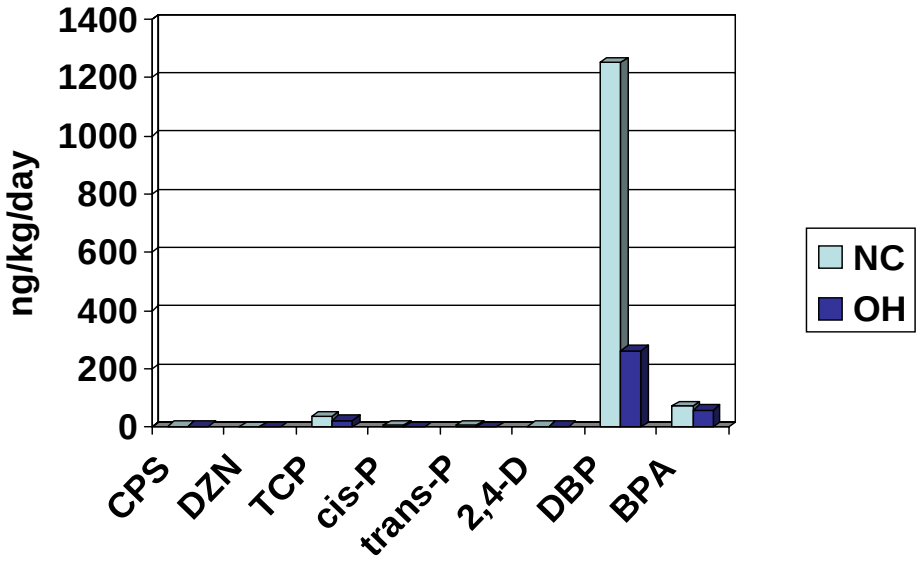

Figure B

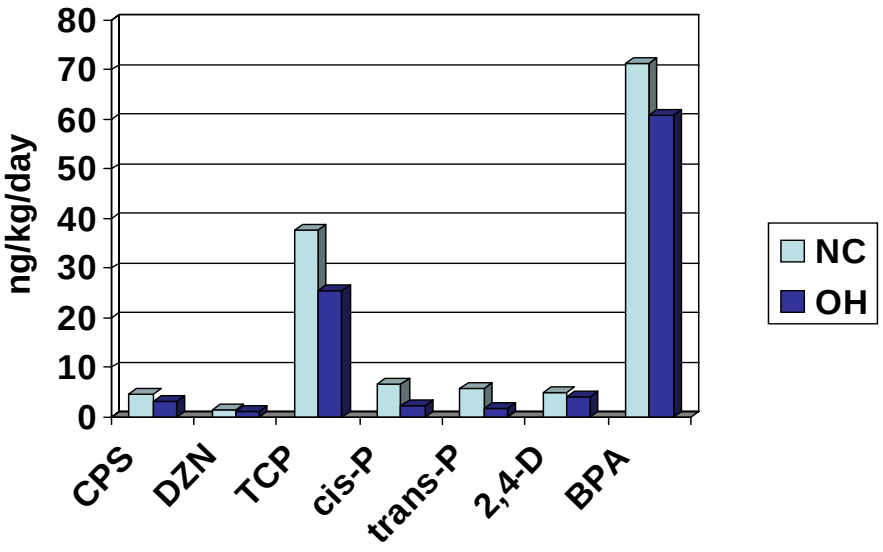

Figure 2.4.2 Estimated Median Aggregate Potential Doses of NC and OH Preschool Children to Eight Pollutants in Their Everyday Environments

Legend: CPS = Chlorpyrifos; DZN = Diazinon; TCP = 3,5,6-Trichloro-2-pyridinol *Cis*-P and *Trans*-P = *Cis*- and *Trans*-Permethrin; 2,4-D = 2,4-Dichlorophenoxyacetic acid; DBP = Di-*n*-butylphthalate; BPA = Bisphenol-A

Note: Figures A and B are equivalent, except Figure B excludes DBP.

Section 1.0. An analysis of variance approach was taken to determine whether these estimates and concentrations differed significantly between 1) day care children and stay-at-home children, 2) children in urban and rural environments, and 3) children in low-income and middle/high-income environments.

The comparisons between the exposures of children and adults in the same households in NC and OH are not discussed in this section. The results in chapter 9 showed that children were generally exposed to significantly higher levels of pollutants than adults in the same household, however, these results were likely due to differences in physiological factors (i.e., ventilation rates and body weights), activity patterns (i.e., hand-to-mouth and object-to-mouth), or consumption of different types of food.

Comparisons between day care children and stay-at-home children: For the nine PAHs and for benzylbutylphthalate via the indirect ingestion route, OH day care children ranged up to 3.3 times higher potential exposures and potential absorbed doses compared to stay-at-home children, and these differences were highly significant. For the dietary ingestion exposure route, highly significant differences existed in potential exposure level and/or potential absorbed dose between OH day care children and stay-at-home children for *cis*- and *trans*-permethrin and for benzylbutylphthalate, with day care children having approximately three times the levels, on average, compared to stay-at-home children. For NC children, potential exposure level or potential absorbed dose for one group (day care children or stay-at-home children) was always less than three times the value of the second group, on average, across the pollutants and exposure routes.

Comparisons between children in urban and rural environments: NC children who lived in urban counties had 3.4 times and 3.7 times higher potential exposures and potential absorbed doses, respectively, to 2,4-D through the indirect ingestion route of exposure compared to rural children, and these differences were highly significant ($p<0.01$). Similarly, OH children living in urban counties had 3.2 to 3.7 times higher potential exposures and potential absorbed doses of each of the nine PAHs through the indirect ingestion route of exposure compared to rural children, and these differences were highly significant.

Comparisons between children in low-income and middle/low- income environments: Between low-income and middle/high-income children in both NC and OH, potential exposure and potential absorbed dose estimates of 2,4-D were highly significantly different under the indirect ingestion route, with low-income children averaging 30% or less of the estimates of middle/high-income children, on average.

Summary: The largest differences between urban and rural children, between day care and stay-at-home children, and between low-income and middle/high-income children in potential exposure level and potential absorbed dose, as well as the most frequent occurrences of significant differences, occurred within the indirect ingestion exposure route for both states. There were relatively few occurrences of highly significant differences between population strata for either aggregated potential exposure levels or aggregated potential absorbed dose among the eight pollutants for which these measures were calculated for the study participants, and no

difference deemed to be highly significant was at least three times larger, on average, for one stratum versus another. There were no highly significant differences in urinary concentrations of 3,5,6-TCP, 2,4-D or pentachlorophenol between any strata.

2.5 Goal 4

The fourth goal of the CTEPP study was to apportion the aggregated potential exposure levels and aggregated potential absorbed dose estimates for the NC and OH children across the inhalation, dietary ingestion, and indirect ingestion routes of exposure. These aggregated potential exposure levels and aggregated potential absorbed doses could be quantified through the three routes of exposure for eight pollutants: chlorpyrifos, diazinon, 3,5,6-TCP, *cis*-permethrin, *trans*-permethrin 2,4-D, di-*n*-butylphthalate, and bisphenol-A. Statistical analyses involved calculating the proportions of the aggregate potential exposure levels and aggregate potential doses by each route of exposure for each child, then fitting a logistic regression model to these proportions to estimate mean proportions as a function of environmental type, urbanicity, and income status.

Figures 2.5.1 and 2.5.2 illustrate the overall estimates of the mean proportions by route of exposure for NC and OH children, respectively. The results show that for both states, the dietary ingestion route was the primary route of exposure to all eight pollutants. Greater than 92% of the aggregated potential exposure levels and aggregated potential absorbed doses of the children were to bisphenol-A, 3,5,6-TCP, 2,4-D, and di-*n*-butylphthalate through the dietary ingestion route of exposure. In addition, about 50% of the aggregated potential exposure levels and potential absorbed doses of *trans*-permethrin, *cis*-permethrin, diazinon, and chlorpyrifos were through the dietary ingestion route of exposure. The OP pesticides, chlorpyrifos and diazinon, contributed most to the inhalation route of exposure for NC and OH children, while the pyrethroids, *cis*-permethrin and *trans*-permethrin, contributed most to the indirect ingestion route of exposure. Therefore, children in both states were predominantly exposed to the eight chemicals through ingestion, primarily dietary in nature.

Mean proportions associated with each exposure route were also calculated by stratum (urban children, rural children, low-income children, middle/high-income children, day care children, stay-at-home children), and statistical analysis was performed to determine whether a particular type of stratum (urbanicity, income level, day care attendance) had a significant effect on the mean proportion for a given exposure route. Results of this analysis showed that there were several highly statistically significant ($p<0.01$) differences in the exposures of NC or OH children between pairs of strata. However, these statistically significant differences between each strata were frequently not realistically meaningful, except in some instances. For example, for diazinon, mean proportions for the inhalation route of exposure differed significantly ($p<0.01$) between low-income children (46%) and middle/high-income children (34%) for NC children.

For the NC and OH children, Table 2.5.1 presents the relative importance of the children's exposures to the eight target pollutants through the inhalation, dietary ingestion, and indirect ingestion routes of exposure.

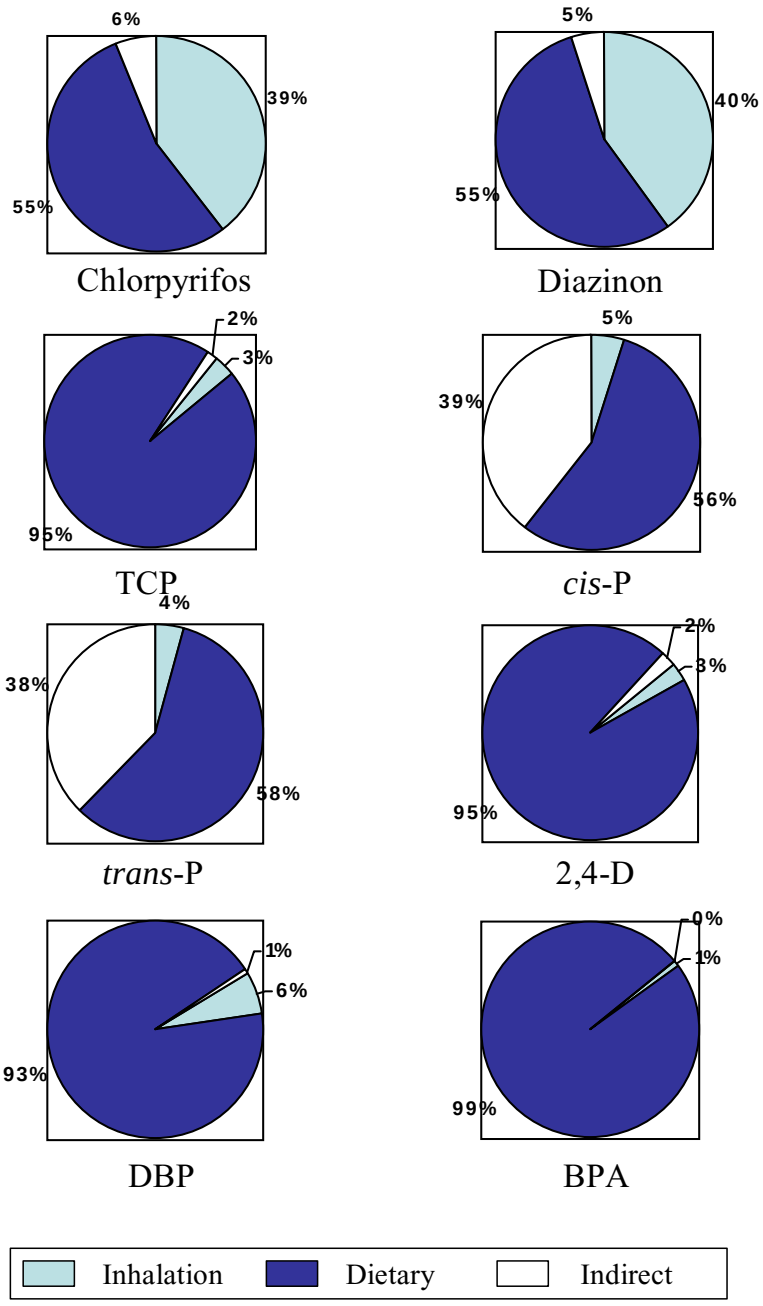

Figure 2.5.1 Estimated Mean Proportion of Aggregated Potential Exposure and Potential Absorbed Dose for NC Children, by Exposure Route

Legend: TCP = 3,5,6-Trichloro-2-pyridinol; *Cis*-P and *Trans*-P = *Cis*- and *Trans*-Permethrin; 2,4-D = 2,4-Dichlorophenoxyacetic acid; DBP = Di-*n*-butylphthalate; BPA = Bisphenol-A.

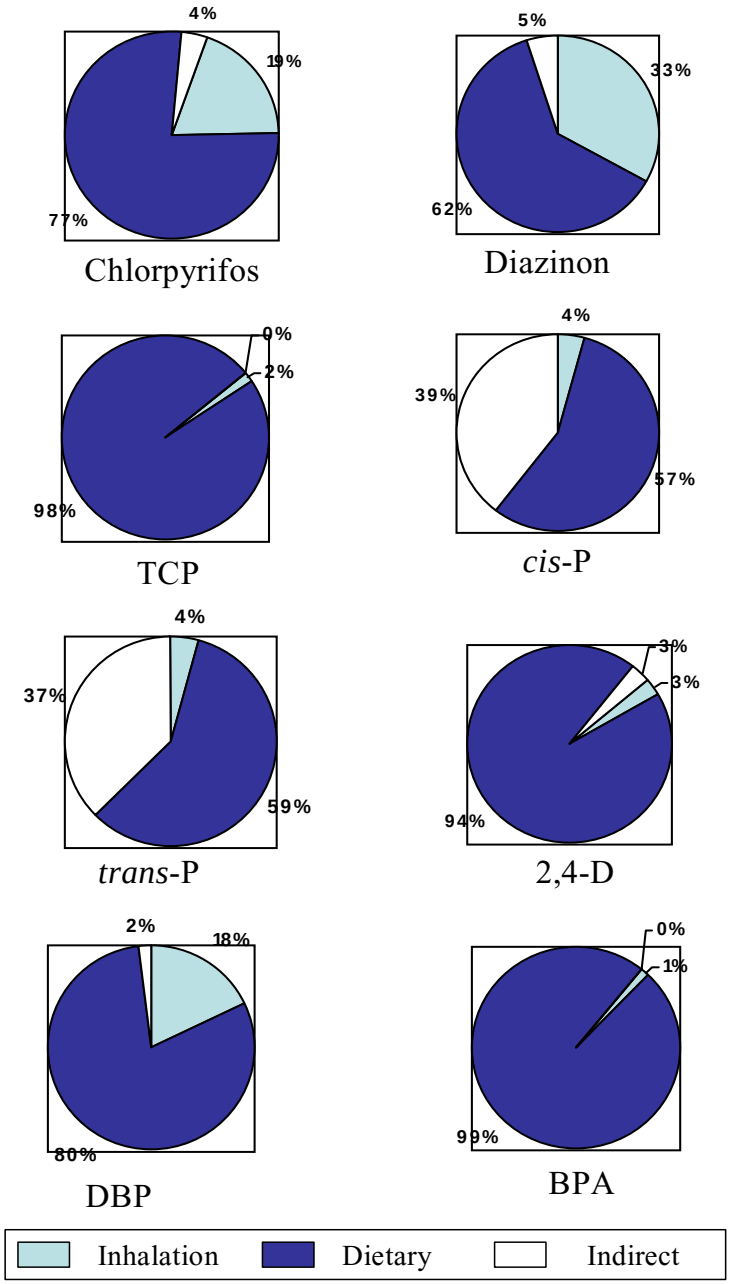

Figure 2.5.2 Estimated Mean Proportion of Aggregated Potential Exposure and Potential Absorbed Dose for OH Children, by Exposure Route

Legend: TCP = 3,5,6-Trichloro-2-pyridinol; *Cis*-P and *Trans*-P = *Cis*- and *Trans*-Permethrin; 2,4-D = 2,4-Dichlorophenoxyacetic acid; DBP = Di-*n*-butylphthalate; BPA = Bisphenol-A. .

Table 2.5.1 The Relative Importance of the NC and OH Children's Exposures to the Eight Pollutants Through the Inhalation, Dietary Ingestion, and Indirect Ingestion Routes of Exposure.

Chemical Class	Pollutant(s)	Apportionment of Aggregated Exposure/Dose
OP Pesticides	Chlorpyrifos	***NC:*** dietary ingestion . inhalation > indirect ingestion
	Diazinon	***OH:*** dietary ingestion > inhalation > indirect ingestion
OP Metabolite	3,5,6-TCP	***NC:*** dietary ingestion > inhalation > indirect ingestion
		OH: dietary ingestion > inhalation > indirect ingestion
Pyrethroid Pesticides	*cis*-Permethrin	***NC:*** dietary ingestion . indirect ingestion > inhalation
	trans-Permethrin	***OH:*** dietary ingestion > indirect ingestion > inhalation
Acid Herbicide	2,4-D	***NC:*** dietary ingestion > inhalation > indirect ingestion
		OH: dietary ingestion > indirect ingestion . inhalation
Phthalate	Di-*n*-butylphthalate	***NC:*** dietary ingestion > inhalation > indirect ingestion
		OH: dietary ingestion > inhalation > indirect ingestion
Phenol	Bisphenol-A	***NC:*** dietary ingestion > inhalation > indirect ingestion
		OH: dietary ingestion > inhalation > indirect ingestion

In summary, the NC and OH children had similar mean proportions of aggregated potential exposure level and of aggregated potential absorbed dose for the eight pollutants across the three routes of exposure considered in this study. The dominant route of exposure for these children was through dietary ingestion for all eight pollutants. The OP pesticides, chlorpyrifos and diazinon, contributed most to the inhalation route of exposure, while the pyrethroids, *cis*- and *trans*-permethrin contributed most to the indirect ingestion route of exposure.