9.0 SUMMARY AND CONCLUSIONS

In an effort to facilitate risk assessments that take into account unique childhood vulnerabilities to environmental toxicants, the National Exposure Research Laboratory (NERL) in the U.S. Environmental Protection Agency's (U.S. EPA) Office of Research and Development (ORD) identified four priority research areas as representing critical data gaps in our understanding of environmental risks to children. These *priority research areas* are: 1) pesticide use patterns; 2) spatial and temporal distributions of residues in residential dwellings; 3) dermal absorption and indirect (non-dietary) ingestion; and 4) dietary ingestion. Several targeted studies were conducted or financially supported by NERL to specifically address these priority research needs. The studies were designed to address the largest uncertainties associated with children's exposure and aimed to produce sufficient real-world data to eliminate excessive reliance on default assumptions when assessing exposure. Significant progress has been made in each of the four priority areas leading to a more comprehensive understanding of the exposures resulting from children's interactions with their environment.

In the area of pesticide use patterns, our studies have taught us that pesticide products are likely to be found in nearly 9 out of every 10 homes. The most frequently applied of these products typically contain pyrethrins and pyrethroids (namely, permethrin, cypermethrin, and allethrin). The applications are more likely to be performed by an occupant than by a professional, with "crack-and-crevice" type applications favored over either the broadcast or total release aerosol types. The application frequencies appear to be higher in warmer climates, but no differences based on population density (urban *vs.* rural) or other socio-demographic factors including race, ethnicity, home type, income, and level of education are evident. Despite much effort in questionnaire development, we have had little success in correlating questionnaire responses with residue measurements. More effort is still needed to improve questionnaires and to ensure uniformity in inventory forms in future studies. Target populations for future studies should be chosen from areas that extend outside the limited geographic regions that have previously been studied to capture divergent use patterns, but previously studied populations should also be included to document trends.

We have learned a great deal about spatial and temporal distributions of pesticide residues. Indoor air concentrations are typically ten-fold higher than outdoor concentrations, but surprisingly high outdoor air concentrations have also been measured. In the absence of any recent application, concentrations in indoor air are strongly influenced by vapor pressure. Immediately following an application, airborne concentrations peak within 24 hours and produce a concentration gradient with levels decreasing with distance from the application site. Southern states do have higher airborne concentrations than Northern states, but there is considerable overlap. Population density (urban *vs.* rural) and income level differences are evident. With surface residues, considerable variability exists not only among rooms but also in different locations within a room. Substantial translocation of pesticides from application surfaces to adjacent surfaces, and from outdoor surfaces to indoor surfaces has been observed. Cleaning activities and ventilation have been found to be important for both air and surface concentrations. Much, though not all, of what we have learned about spatial and temporal variability has come from organophosphate pesticides, and more studies with pyrethroids are needed.

These studies have added merit to earlier hypotheses that dermal transfer and indirect ingestion are important routes of children's exposure to pesticides. In fact, the shift to less volatile, more organophilic pyrethroid pesticides magnifies the importance of particle-bound transfer and implies an increased significance of indirect ingestion. Substantial challenges still exist in this area. One challenge is to incorporate into estimates of dermal exposure what we have learned through laboratory studies of the importance of skin condition, contact motion, and number of contacts. Another challenge is to standardize the collection methods used to measure the surface residues that are a key part of dermal exposure estimates. A third challenge is to improve our indirect ingestion exposure algorithms to ensure that we are not missing major transfer mechanisms that may bridge the gap between what we are estimating as intake and what we are measuring as excreted.

Analysis of the dietary ingestion components of our studies produce intake estimates that suggest dietary ingestion may often be the dominant route of exposure (even with pyrethroids despite the increased importance of the dermal and indirect ingestion routes). Low detection frequencies in food measurements, however, increase uncertainty, as does the questionable reliability of duplicate diet estimates for young children. Improvements are still essential in both the sample collection and the chemical analysis methods. Large differences in dietary exposure estimates among children in the same studies point to a need for a better understanding of the variability in dietary exposure.

Clearly, more information is needed to assess the relative importance of the exposure routes under different conditions and with pesticides from diverse compound classes. More work is necessary to reconcile aggregate exposure estimates with levels of biomarkers measured in urine. Moreover, more work is needed to better understand how exposures and important exposure factors differ across age groups, as children move through different developmental stages.

We anticipate that the analyses presented in this report will be useful to the EPA Program Offices, including the Office of Pesticide Programs and the Office of Children's Health Protection, in their risk assessment and management activities. Although much of this high-quality, real-world data has already been made available to the Program Offices piecemeal and by publication in the peer reviewed literature, we expect consideration of the data collectively to provide added value to the results of individual studies. Admittedly there are limitations inherent in the comparisons: studies were performed in different seasons, in different years, using different methods, and with different sample sizes. We are confident, however, that these analyses will facilitate more accurate exposure and risk assessments, thereby strengthening regulatory actions aimed at reducing risk, and helping to ensure that pesticides are appropriately regulated.