

## Exposures from Indoor Spraying of Chlorpyrifos Pose Greater Health Risks to Children than Currently Estimated

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Recent findings of indoor exposure studies of chlorpyrifos indicate that young children are at higher risks to the semivolatile pesticide than had been previously estimated [Gurunathan et al., *Environ Health Perspect* 106:9–16 (1998)]. The study showed that after a single broadcast use of the pesticide by certified applicators in apartment rooms, chlorpyrifos continued to accumulate on children's toys and hard surfaces 2 weeks after spraying. Based on the findings of this and other research studies, the estimated chlorpyrifos exposure levels from indoor spraying for children are approximately 21–119 times above the current recommended reference dose of 3 µg/kg/day from all sources. A joint agreement reached between the U.S. Environmental Protection Agency and the registrants of chlorpyrifos-based products will phase out a number of indoor uses of the pesticide, including broadcast spraying and direct uses on pets. While crack and crevice treatment of insects (such as cockroaches and termites) by chlorpyrifos will still continue, it appears prudent to explore other insect control options, including the use of baits, traps, and insect sterilants and growth regulators. To ensure global protection, adequate dissemination of appropriate safety and regulatory information to developing regions of the world is critical, where importation and local production of chlorpyrifos-based products for indoor uses may be significant. **Key words:** alternative insect control, chlorpyrifos, exposure assessment, health risks to children, indoor pesticide use, international trade in pesticides, semivolatile pesticides, termite and roach control. *Environ Health Perspect* 106:299–301 (1998). [Online 28 April 1998] <http://epbnet1.niehs.nih.gov/docs/1998/106p299-301davis/abstract.html>

Chlorpyrifos (common commercial names are Dursban and Lorsban) is one of the most commonly used pesticides in the indoor environment today. It has been used as an active ingredient in agricultural formulations, flea collars and dips, animal sprays and shampoos, crack and crevice sprays, and subterranean termite treatment. According to the EPA, 972 registered products contain chlorpyrifos, including widespread uses for termite and roach control and home and garden use (1). When a chlorpyrifos-based product is sold as a concentrate (mostly used by commercial exterminators), it has the signal word "warning," indicating a very toxic product (i.e., it may be fatal if swallowed), as opposed to most household products that may have the signal word "caution," indicating only moderately toxic formulations. These product labels only include general guidelines for professional applicators in determining safe times for reentry following the spraying of the product, such as in broadcast applications. Even these label references for professional applicators are inconsistent, typically only referring to qualitative measures such as whether the pesticide appears to be dry, and simply do not provide adequate guidelines concerning the safe reentry of household inhabitants or their personal possessions in the postapplication period.

Broadcast spray applications of chlorpyrifos were recognized as an important public health concern in the mid-1980s by

the California Department of Health Services (2,3). Subsequent studies by researchers at Rutgers University and the Canadian government documented that residues could accumulate over time on untreated surfaces and that potential exposures of children following such applications were likely to exceed the no observable adverse effect level for chlorpyrifos (4,5). Parallel investigations were conducted by the state of California for total release (fogger) applications (6).

Recent studies by Gurunathan and her associates at the Environmental and Occupational Health Sciences Institute at Rutgers University (the EOHSI study) indicate that broadcast spraying of chlorpyrifos in the indoor environment may pose considerable risk to public health (7). In this well-conducted study, applications of chlorpyrifos by trained applicators following recommended procedures produced pesticide residues on children's toys and on hard surfaces in test rooms approximately 21–119 times above the recommended reference dose (RfD) of 3 µg/kg/day for chlorpyrifos exposure to children from all sources. The experimental protocols in this study (i.e., a one-time broadcast spray application) simulated conditions that should have led to a reasonably realistic estimation of exposure to chlorpyrifos. In facilities such as day care centers, schools, and homes, where chlorpyrifos-based products may be frequently sprayed to control

insect infestations, there can be cumulative exposures that are much higher than those currently estimated from this and other pesticide exposure studies based on single applications.

Earlier studies have demonstrated that chlorpyrifos air concentrations peak well after broadcast applications and that substantial redistribution of chlorpyrifos from treated to untreated surfaces can occur in the first 24 hr after applications (4,5). The EOHSI study followed the manufacturers' directions for spray application and showed that chlorpyrifos does not dissipate or settle down when deposited in the particle phase. Chlorpyrifos, like many semivolatile pesticides that are applied as pressurized sprays, functions both as an aerosolized particle and as a gaseous compound. After initial deposition, the compound vaporizes into the gas phase 12 hr after spraying and is airborne, at which time it becomes absorbed onto various solid surface areas, including furniture and children's toys. The EOHSI study demonstrated that the compound continued to be released into the gas phase and became deposited on a variety of solid surfaces for at least 2 weeks after a single broadcast application. In accord with the manufacturers' recommended practices for a standard apartment style room, no toys were in the test rooms during the spraying period. Children's toys (consisting of plush and plastic materials) were placed in the test rooms 1 hr after spraying, and measurements of the accumulation of chlorpyrifos residues on these toys were made on days 1 through 14. The EOHSI study showed that these commonly used children's toys contained consistently high concentration of chlorpyrifos residues over a 2-week period, thus serving both as a chemical sink and a long-term reservoir for the toxic compound.

In recent years, the EPA formally reviewed more than 200 legal claims submitted by the principle manufacturer (DowElanco, Indianapolis, IN) and from other surveillance data, such as those provided by the California Pesticide Illness Surveillance Program and the American Association of Poison Control Centers (8).

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Among the symptoms reported to be linked with chlorpyrifos applications are headache, dizziness, loss of coordination, respiratory distress, abdominal cramps, nausea, vomiting, diarrhea, blurred vision, increased secretions (tearing, sweating, salivation), mental confusion, and muscular weakness. Because exposure from spray applications was assumed to reach peak levels within a few hours after use and to fall off rapidly, researchers have generally been unable to understand or have been slow to accept how these disease symptoms could be associated with chlorpyrifos exposure.

Chlorpyrifos is widely used in insect control programs worldwide and has also been linked with respiratory hypersensitivity reactions (9). Additional studies need to consider whether pesticide treatment for insects such as cockroaches could heighten allergic response because cockroach antigen remains one of the most commonly reported causes of asthma (10,11). In addition, a number of cases have been reported of birth defects in children born to mothers who have previously had healthy babies. Prenatal exposure to normal levels of chlorpyrifos has been identified as a possible explanation of these defects (12). The suggestion that routine exposures to chlorpyrifos could account for these unusual birth defects has been dismissed by those who have argued that the levels of exposure from such routine spraying were not sufficient to produce any biological effects and that the reported defects are not known to share any common etiology. In fact, the causes of most birth defects are generally unknown. A recent expert panel that reviewed the relevant toxicological and public health data for the chemical industry concluded that current levels of chlorpyrifos exposure were unlikely to account for many reported health problems, including birth defects (13). However, the study by the EOHHSI team (7) provides important new evidence that cumulative exposures to this commonly sprayed compound could be one to two orders of magnitude greater than previously believed in the indoor environment.

In June 1997, in a decision reached between the EPA and the principle producer of chlorpyrifos products (the EPA Agreement), the registrants voluntarily agreed to halt sales of products used directly on pets, including sprays, shampoos, and flea dips, and in foggers and broadcast applications to carpets in homes (1). Even though flea collars, most notably, are not involved in this voluntary recall, the large volume of products affected indicates that initial changes stemming from the agreement will not be seen until 1998 (other

uses that will continue include spot treatments for closets and dresser drawers, ant trails, furniture and flooring, areas under cabinets, beneath sinks and appliances, and around garbage cans, plumbing, and utilities). The EPA Agreement contains several key provisions designed to protect public health in the United States. For example, working together, the EPA and the registrants agreed to develop new policies for recommended application procedures, protection methods, and labeling (1). Further, under the terms of the EPA Agreement, the principle registrants will provide funding for the Poison Control Center Stewardship Project at the University of Minnesota, which monitors chlorpyrifos-related incidents throughout the United States (1).

In addition, the registrants appointed an expert panel to direct a review study on the possible health effects associated with the use of and exposure to chlorpyrifos (1). This expert panel concluded on 31 July 1997 that "there is insufficient evidence of harm to human health to warrant further investigation" and that "the available scientific evidence provides no basis for concern" (13). However, a three member minority of the eight member panel recommended further epidemiological study "of a group such as production workers with long-term potential exposures at levels higher than the general population." On the other hand, the expert panel did not mention concern for any other specific group. Based on the EOHHSI study, it would appear that the statement made by the industry's expert panel needs to be seriously reexamined, so that further toxicological and epidemiological studies are carried out to evaluate potential public health impact that result from greater degree of exposures of chlorpyrifos to young children.

Finding safer modes of treatment for insect infestations such as cockroaches remains an important public health issue because these pests carry diseases and they may also be allergenic. Basic hygiene to remove residues that attract cockroaches and to eliminate their natural indoor habitats can do much to reduce infestations in homes, schools, and other institutions. Chemical treatments may also be appropriate and could be employed under certain circumstances, provided treatments are targeted to areas where cockroaches hide and are not sprayed over large areas where children and pets could be exposed. Crack and crevice treatment used to control insects (such as cockroaches) will generally produce much lower air and surface residues in residences than will broadcast applications. Nevertheless, it seems prudent to explore other options for such insect control

measures rather than exclusively relying on chemical treatments. Alternatives to broadcast spraying include the use of baits and traps and applications of materials at the room perimeter. The use of baited sticky traps or bait stations that incorporate gel formulations containing less toxic ingredients, such as abamectin, hydramethylnon, and sulfuramid, in infested areas can be quite effective in cockroach control. In addition, insect sterilants or growth regulators such as hydroprene or fenoxycarb can also be effective (14). When using baits and traps, it is important that they be replaced regularly, so that the small dark places where they are most effectively placed do not become new habitats for cockroaches or other pests once their active ingredients dissipate.

In the past, the use of baited sticky traps or bait stations was not considered the most effective cockroach control measure and therefore not the method of choice. However, recent advances in technology have dramatically changed the relative effectiveness of this alternative approach to pest management. For example, the incorporation of an aggregation pheromone into the typical baited sticky trap has been shown to increase the effectiveness of the traps by over 300% (15). As these new technologies become available and are used as primary components of integrated pest management plans, the use of chlorpyrifos as a means of insect control should decrease.

Other spray applications of chlorpyrifos, such as injection of the pesticide into a building foundation for the treatment of termites, are less likely to result in hazards to household residents if properly applied. However, a number of recent lawsuits indicate that misapplications into heating ducts and other circulating systems have endangered applicators and residents. While it is believed that the half-life of chlorpyrifos is around 30 days (16), there are reports that show the presence of the pesticide several years—as much as 2 and 8 years—after termite treatment of home foundations or concrete slabs by chlorpyrifos injection (17–19). In one case, chlorpyrifos was injected into the foundation of a church building that contained a heating duct system embedded in concrete slabs. This method of injection caused the pesticide to be pumped into the ducts; thus, it circulated in the heating system for more than a year before the source was determined. A former pastor and two employees of the church filed a lawsuit alleging various health problems from the prolonged exposure and seeking compensation in the amount of \$2 million (20). In addition,

several lawsuits have been settled that involved inappropriate or inadvertent applications to heating ducts, furniture, and bedding, often resulting in heavy cleanup costs and hazardous exposure to residents and applicators (21).

Additional research should be carried out to replicate the findings of the EOHSI team. The results of the EOHSI study (7) may account for some of the health effects reported thus far and suggest why several earlier field reports have found relatively high levels of chlorpyrifos and other pesticides in household dust (22,23). Recognizing the possible link between relatively high levels of pesticides found in domestic settings and observed health effects, we should take a precautionary approach in any future policy decisions. This precautionary approach should focus on practical means that reduce crack and crevice use, spot treatments, and termite control use in favor of less toxic alternatives and other integrated pest management practices. A number of issues still remain to be resolved, e.g., exposure from flea collars must be assessed, especially as young children often are in direct contact with their collared pets.

Meanwhile, both public and private users of materials such as chlorpyrifos should be fully informed about the potential for increased exposures for indoor uses of semivolatile materials. Commercial and private applicators of pesticides should be trained in specific practices that minimize human exposure from the spraying of such pesticide products, especially in the environments of young children and those with sensitivity reactions. To facilitate these efforts, information concerning the use of pesticides, including those containing chlorpyrifos, may be obtained through the Oregon State University/U.S. EPA, National Pesticide Telecommunications Network and Web site (24).

The move to restrict all broadcast spray applications of chlorpyrifos is a welcome one, especially in light of the findings presented in the EOHSI study (7). However, serious questions must now be raised about what will happen to current stocks of products containing chlorpyrifos. Export policies should be devised that do not expose others to risks that are now considered unacceptable in the United States. The public health consequences of the EOHSI study may have worldwide significance and could extend from the United States to other developed and developing countries. In the past three decades, global pesticide consumption has risen dramatically in both agricultural applications and domestic use. For example, between 1960 and 1992, worldwide pesticide sales in dollar terms

(uncorrected for inflation) rose at an annual rate of 11.2% (25). When corrected for inflation in developing country markets such as China, India, Brazil, and Mexico, it is estimated that future growth rates in pesticide sales will range between 2.5 and 3.5% per year (26). In 1994, worldwide sales of pesticides were estimated to be \$27.8 billion, of which the United States exported nearly \$2 billion of pesticide products overseas (27,28). Between 1992 and 1994, the United States exported some 170 million pounds of pesticide products containing all organophosphate compounds, including chlorpyrifos (27).

Specific U.S. export figures for chlorpyrifos (a chlorinated organophosphate compound) amounted to about 24 million pounds during 1992–1994 (27). In the United States and other developed countries, sprayed chlorpyrifos is one of the most widely used compounds in the indoor environment. In addition, some developing countries such as India and Brazil domestically manufacture active ingredients in commonly used pesticide products, including organophosphates and carbamates. They are thus able to produce and export pesticides such as chlorpyrifos-based formulations to neighboring countries in their region. Many of these countries do not have stringent protection for their workers, adequate regulatory safeguards, updated labeling guidelines, or educational materials concerning proper indoor uses (29). In short, the EOHSI study (7) raises a number of critical public health policy issues that need to be addressed at both the domestic and international levels.

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