Evaluation of Two Studies Monitoring Pesticides in the Air and Soil at South Woods Elementary School in Hastings, Florida

FLORIDA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

DIVISION OF AGRICULTURAL ENVIRONMENTAL SERVICES

BUREAU OF PESTICIDES

SCIENTIFIC EVALUATION SECTION

September 4, 2007

This review evaluates potential human health risks that may occur as a result of pesticide levels in air that were reportedly present in Hastings, Florida. Analytical results were provided to the Florida Department of Agriculture and Consumer Services (FDACS) by parties not affiliated with the Department. Although a good faith effort was taken to ensure that the information provided to the Department was complete and accurate, the conclusions in this report nevertheless rely to an extent on the quality of data that was provided. Conclusions drawn in this review are based on a specific set of unique circumstances present in a particular locale within the State of Florida, and do not necessarily apply to other exposure scenarios in which different environmental conditions may be present. The information utilized by the Department in formulating the conclusions contained within this report includes research findings obtained from publicly available scientific literature, pesticide registrants, federal authorities, as well as agencies both within, and outside the State of Florida. This review includes both quantitative and qualitative information. The Scientific Evaluation Section welcomes comments and discussion of these issues.

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The author(s) can be reached by mail at:

Bureau of Pesticides
3125 Conner Boulevard,
Building No. 6, Mail Station 1650
Tallahassee, Florida 32399-1650
(850) 487-0532
Web Site: http://www.flaes.org/pesticide/scientificevaluation.html

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I. Executive Summary

In February of 2007, the Florida Department of Agriculture and Consumer Services (FDACS) became aware of a series of news articles published by the St. Augustine Record, the Florida Times Union, and the Associated Press that reported unsafe levels of semi-volatile pesticides in the air near South Woods Elementary School in Hastings, Florida. The air monitoring was conducted by two Pedro Menendez High School students on December 6-14, 2006, as a part of a science fair project, in cooperation with the Pesticide Action Network of North America (PANNA). PANNA is a non-governmental environmental group that "works to replace pesticide use with ecologically sound and socially just alternatives." The organization provided considerable technical assistance to the students in the form of training on sample collection, provision of sample analyses, and data interpretation. In April of 2007, PANNA released a report on the project entitled, "Air Monitoring for Pesticides in Hastings, Florida December 2006" (PANNA, 2007). The report identified the pesticides endosulfan, diazinon, and trifluralin in air samples collected from a residence 0.3 miles north of the school property. The PANNA report also concluded that endosulfan and diazinon, but not trifluralin, were present in air in the vicinity of the school at unsafe levels.

Subsequently, the St. Johns County School Board (SJCSB) contracted the consulting firm MACTEC to conduct air and soil sampling on the school grounds on February 27th, 28th, and March 5th, 2007. The MACTEC report entitled "Report of Pesticide Testing Services South Woods Elementary School" (hereafter referred to as the SJCSB report) noted that workers were seen spraying pesticides on the field adjacent to the school during two of the three days of sampling but did not report any pesticide detections in the air inside of the school, in outdoor air, and only trace levels in soil sampled on the school property.

Both the PANNA report and the SJCSB report can be downloaded from the PANNA website (PANNA, 2007).

FDACS has reviewed the available information and concludes that the levels of pesticides found in the air near South Woods Elementary do not pose an imminent or long-term health threat to students or faculty at the school. This conclusion is based upon the following factors:

1. **The maximum detected levels in the air at or near the school are well below acceptable guideline values established for these compounds by various U.S. federal agencies that are generally recognized as authoritative bodies in assessing risks to human health. These various authoritative bodies have set health-based comparison values, which are guideline concentrations in air to which adults and children may be continuously exposed over extended periods of time (*e.g.,* weeks to years) without any appreciable risk of harm:** Although there are no enforceable federal standards *per se* for acceptable levels of these pesticides in air, federal agencies such as the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR), and other authoritative federal bodies have calculated, with substantial safety margins, reasonably

safe levels of these compounds in air. The maximum levels reported by PANNA in the air near the school were in every case well below the federal guidance levels for these compounds: for endosulfan, the maximum detected concentration was 626 ng/m^3, which is less than the USEPA RfC (reference concentration) of 21,000 ng/m^3; for diazinon, the maximum detected concentration was 897 ng/m^3, which is less than the U.S. Public Health Service intermediate duration MRL (Minimum Risk Level) of 10,000 ng/m^3, and the chronic health-based comparison value of 3,300 ng/m^3 used by USEPA Regions 3, 6, and 9. Furthermore, endosulfan and diazinon were not detected in the SJCSB study. Although the minimum detection limits (MDLs) in the SJCSB study (*i.e.*, 3,300 ng/m^3 for endosulfan, and 2,100 ng/m^3 for diazinon) were greater than MDLs reported in the PANNA study, the SJCSB MDLs were nevertheless below the respective RfC or MRL values for these compounds, demonstrating that these compounds were not present in air at the school at, or even somewhat below, federal guidance levels. Neither the PANNA study nor the SJCSB study concluded that trifluralin was at a level of concern; it was also below health-based comparison values used by federal authoritative bodies.

Table 1

Pesticide	Maximum Concentration Detected by PANNA (ng/m3)	Federal Authoritative Body Health-Based Comparison Value (ng/m3)
Endosulfan	626	21,000 USEPA RfC
Diazinon	897	10,000 ATSDR MRL

2. **No apparent health effects have been reported at the school:** The news articles indicated that "no student, teacher, visitor or neighbors of the school have reported becoming ill." This observation is consistent with the U.S. Department of Health and Human Services conclusion that, "studies have not shown harmful human health effects resulting from airborne contamination of areas surrounding fields where diazinon has been used" (ATSDR, 2006).
3. **There is no unacceptable risk to the children at the school based on the Margin of Exposure (MOE) calculation that is used by the USEPA as part of the risk assessment process:** If the USEPA equation for calculating inhalation risk is used for a scenario in which a one-year-old child is breathing the *maximum* concentration of diazinon or endosulfan in air reported by PANNA for a realistic 2-hour duration, there is no unacceptable risk. The calculated risk is even lower for older children who are likely to be attending the school.
4. **Scientific studies have not demonstrated adverse health effects in people exposed to similarly low levels of these pesticides in air:** FDACS has reviewed the scientific literature on the potential health effects of these active ingredients and on the levels of these pesticides reported in air both indoors and outdoors in agricultural, urban, and remote areas having little or no pesticide use. Based on that review, the levels detected in the air in Hastings are similar to, or less than those reported in many other studies in which adverse health effects did not result. Moreover, FDACS could find no evidence either from its review of the literature or from the PANNA and SJCSB reports that any

adverse health effects have been documented in humans or animals following inhalation of these compounds at levels in the range of those reported in Hastings, unless there was also significantly greater oral and dermal exposure occurring at the same time. The adverse health effects reported as being associated with the three compounds involve studies in which experimental laboratory animals or humans were exposed to significantly higher toxic levels of the these compounds. Many of these reports were cases of intentional poisoning or involved occupational or residential settings where the pesticide products were not used in accordance with the product label.

5. **No agricultural misuse was found.** The FDACS Bureau of Compliance Monitoring conducted a pesticide use inspection and reviewed grower records for the agricultural fields adjacent to the school. No evidence of misuse of pesticide products was found.
6. **The USEPA has evaluated and approved the use of these pesticides as they were used in Hastings and has concluded that there is reasonable certainty that no harm will result to children or adults when used as directed:** All three of the pesticides reported in the air near the school have been approved for use on numerous food crops, and the USEPA has considered their risks to be acceptable for infants, pregnant women, and the general public when the products are used according to their respective labels for the approved uses. The USEPA did not specifically include an evaluation of potential adverse health risks from pesticides volatizing from agricultural fields. However, when the Agency conducted its risk assessment for each of these pesticides, a safety factor (*i.e.*, “uncertainty factor”) for children was combined, as warranted, with other safety factors already included in the risk assessment. Consideration was given to the intake from all combined food crops on which these pesticides are used, and also from drinking water and other likely sources of exposure. Potential risks from the major routes of exposure (*i.e.*, oral, dermal, and inhalation) were combined in the USEPA risk assessments, and the risks were added in cases where simultaneous exposure to other pesticides having similar modes of action (*e.g.*, other organophosphate or organochlorine insecticides) might be expected to occur.
7. **FDACS has concluded that while the PANNA and SJCSB studies both appear in most respects to have been reasonably conducted in a manner consistent with accepted practices, the PANNA risk calculations contain assumptions that result in overestimated risk:** The conclusion by PANNA that there are unacceptable risks to children at the school from the concentrations of endosulfan and diazinon in the air are based on the assumption that a one-year-old child will be continuously outdoors near the edge of the field for 24 consecutive hours. In reality, children at the school are older, are outdoors on the grounds for perhaps an hour or two per day, five days or less per week. While it is appropriate to assume maximum air concentrations when conducting an initial screening for risk, it is more appropriate to use an average or upper-bound value in the refined risk calculations. However, even if maximum air concentrations are used in an appropriately conducted risk assessment in which human equivalent doses are applied in conjunction with appropriate exposure durations, the margins of exposure and subsequent risks are within an acceptably protective range for children.
8. **Pesticide levels in air that were reported by PANNA likely represent high end exposure levels:** Since these pesticide product labels limit the number of applications to only a few times per year, and applications were occurring on at least some days during both studies, it is reasonable to conclude that the level of the three pesticides in air would

be less than that reported in the PANNA study at other times such as when crops are not being grown on the fields and other times when pesticide applications are not occurring.

While neither study demonstrated that children attending South Woods Elementary School or nearby residents are breathing dangerous levels of pesticides as a result of agricultural activity in the area, the issues of children's exposure to pesticides and movement of airborne pesticides from agricultural fields are legitimate and important areas of inquiry. The presence of semi-volatile pesticides in air following agricultural use had not previously been identified in Florida as being a cause of pesticide exposure incidents or injury. With the increasing frequency of residential developments and other non-agricultural land uses in rural areas, the topic will likely continue to be a focus of attention. Furthermore, as the USEPA considers implementing restrictions on the use of fumigants which may include the requirement of buffer zones for some pesticides, the need to monitor pesticide levels in air will continue to grow. As resources allow, FDACS hopes to enhance its capacity to monitor air samples for pesticides and to model the dispersion of pesticides in air. In addition, the Department plans to pursue a collaborative effort among stakeholders to develop guidance for pesticide applicators to minimize potential drift to schools and other sensitive sites.

Apart from the conclusions presented above and further discussed below, this summary report compares and contrasts the PANNA and SJCSB studies as well as presents FDACS' interpretation of the monitoring data. In addition, the report discusses the special risks posed to children from exposure to toxic substances, the potential health effects resulting from exposure to chemical mixtures, and areas of uncertainty in the assessment.

II. Comparing Two Air Monitoring Studies

A. Study Designs

Both the PANNA report and the SJCSB report provide useful information in determining levels of pesticides in air at or near the school. However, it is difficult to directly compare the results and conclusions reached in the two reports for several reasons:

- The health-based comparison values used in the two reports (*i.e.*, levels of pesticides in air considered to be without appreciable health risk) were vastly different.
- The PANNA air samples were collected at a distance of approximately 0.3 miles north of the school property, whereas the SJCSB air samples were collected on school grounds, both inside the school and outdoors on the southeast corner of the school property adjacent to an agricultural field.
- The PANNA and SJCSB analytical methods, although similar in several respects, differed greatly in their minimum detection limits (MDLs) for each analyte. However, in both studies, the MDLs were well below the health-based comparison values used by PANNA and MACTEC for the three pesticide active ingredients.
- The air samples that were collected for the two reports were sampled at different times of the year (*i.e.*, December vs. March) and for different durations (*i.e.*, 24-hours vs. 8-hours or less).

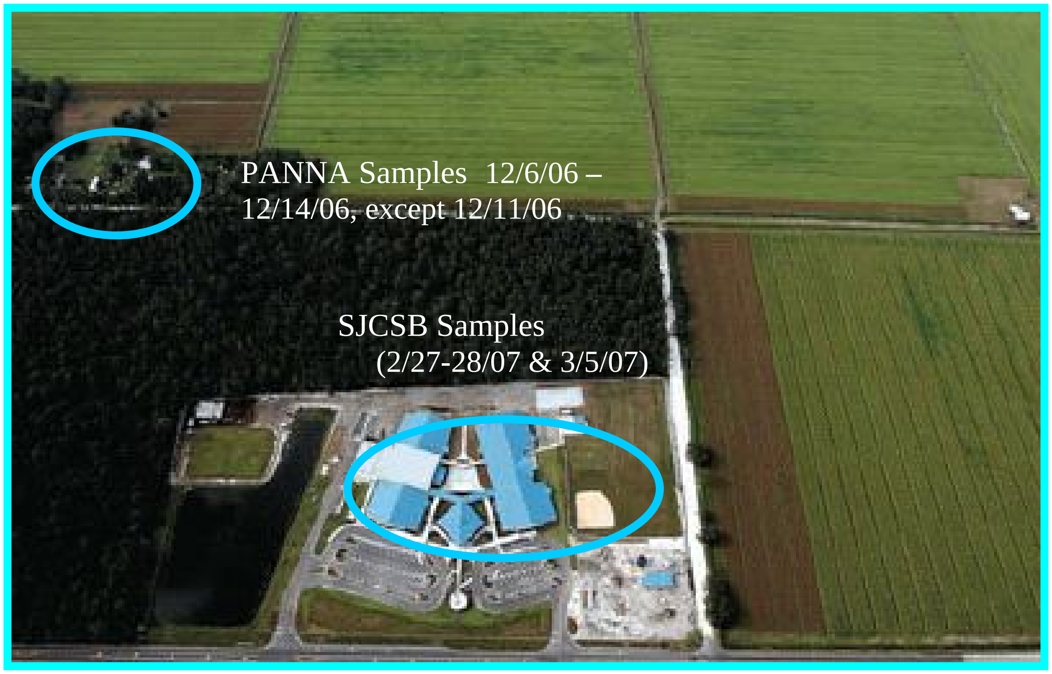
Based on information in the PANNA report, endosulfan and diazinon may have been selected for inclusion on the list of pesticides to be tested based on indications from a farm worker that these pesticides were being used on the field. However, it is unclear whether the PANNA analytical screen also tested the air for other compounds that were not detected. Similarly, it is unclear whether the SJCSB tested the air for compounds other than the three pesticide active ingredients that were reported by PANNA as being present in the air in Hastings. If other pesticides were tested for and not found, or if other pesticides were detected but not reported, that would constitute relevant information that should be included in the risk assessment, although FDACS has no reason to believe at this time that either of those scenarios are in fact the case.

The following table compares the PANNA and SJCSB studies:

Table 2
Comparing Two Air Monitoring Studies in Hastings, Fl.

Variable	PANNA study	SJCSB study
Dates of air sampling	December 6th through 14th, 2006 (excluding 12/11)	February 27th, 28th, and March 5th, 2007
Duration of air sampling	21 to 29 hours	1 to 8 hours
Analyst on site throughout sampling period?	No	Yes
Pesticide application during sampling?	Yes	Yes
Air sample collection site	Approximately 0.3 miles from the school	On the school property, both indoors and outside

Sample Locations



http://staugustine.com/stories/021107/news_4393943.shtml

From December 6 to 14, 2006, two Pedro Menendez High School students conducted an air monitoring project at a residence located approximately 0.3 miles north of South Woods Elementary School. The students collected a total of eight 24-hour (approx.) air samples over that time. The samples were analyzed and interpreted by PANNA and reported in April, 2007 (PANNA, 2007). In response to the PANNA study, MACTEC, a consulting firm hired by the St. Johns County School Board (SJCSB), collected independent air and soil samples on the school grounds on February 27, 28, and March 5. MACTEC researchers collected three air samples inside the school, three air samples outside of the school on the southeast corner of the school property adjacent to an agricultural field, and three soil samples on the school grounds (SJCSB, 2007).

Neither of the studies directly measured children's exposure to pesticides. Although the SJCSB study tested indoor air, where children spend most of their time at the school, and also outdoor air and soil on the school grounds where children are sometimes present, both studies measured the concentration of pesticides in a particular area rather than the level of pesticides in the air of specific children. Children spend only part of their time at the school, and an even smaller part of their time outdoors on the school grounds. Personal air monitoring devices attached to the children's clothing were not employed in either of the studies, and urine samples from the school children were not collected, so there was no measure of the children's actual exposure.

Sampling Durations and Detection Limits

The PANNA study sampled air for periods of 21 to 29 hours per sample, whereas the SJCSB study sampled from 1 to 8 hours. The longer sampling time employed by PANNA enabled the compounds of interest to be detected at lower levels than the shorter sampling times used in the SJCSB study. Although the SJCSB researchers reported higher pesticide detection limits than PANNA, the SJCSB sampling times and durations more appropriately represent the times and durations during which students might be present on a typical school day. Table 3 presents the minimum detection limit for each of the analytes in the two studies.

Table 3
Comparing Detection Limits in the Two Studies

Analyte	Detection Limit (ng/m^3)
PANNA	
Endosulfan I isomer	8.9
Endosulfan II isomer	14
Diazinon	18
Trifluralin	45
SJCSB	
Endosulfan (total)	3,300
Diazinon	2,100
Trifluralin	8,300

Another difference between the studies is that the SJCSB samples were collected more than two months after the PANNA samples were collected (PANNA samples: December 6-14, excluding December 11th; SJCSB samples: February 27, 28, and on March 5th). The same pesticides are not necessarily applied at all times throughout of the year since the state of the crop and the pest pressure will partly dictate the need for treatment. Moreover, pesticide labels, such as those for the three compounds detected by PANNA at these fields, typically allow only a few applications per year on a given field. In addition, it is very likely that pesticides are not applied on a significant number of days throughout the year, such as periods during which crops are not being grown on the fields. Nevertheless, both reports indicated that pesticide applications had taken place over some of the sampling days. (The PANNA report indicates that pesticide applications were observed on December 6th and 13th, and that a field worker indicated that the pesticides applied on December 13th were diazinon and endosulfan. The SJCSB report indicates that workers were seen applying pesticides on February 27th and 28th, but the report does not specify what pesticides were applied. Differences in temperature patterns, wind speed and direction, and weather events between December and March also likely affected the levels of pesticides detected in the air at these different times.

Sample Locations

The PANNA air samples were collected on the property of a private residence located approximately 0.3 miles north of the school property. However, the eastern edge of the school's property and the sampling location at the residence were similar distances (approximately 65 ft.) from agricultural fields, albeit different agricultural fields. The PANNA samples collected on the private residence were approximately 3 feet away from a shed containing undisclosed items. The SJCSB samples were collected on the school property, both inside of the building and outside on the school grounds.

The PANNA report notes that trees near the PANNA sample site might have blocked some of the airborne pesticides from reaching the sample tubes. However, the school also appears to be bordered by a stand of trees on the north side, perhaps to a greater extent than the residence. While it is possible that trees may serve as a buffer to prevent some of the airborne pesticides from reaching the sample collection sites, it is not clear to what extent that is the case.

B. Analytical Chemistry Methods

Based on the information provided to FDACS, which included the final reports, but not any of the raw analytical data and other supporting material (chromatograms for primary and confirmatory analysis, calibration plots, quality control samples, chemical standards preparation logs, sample collection/extraction logs, *etc.*), both the PANNA and SJCSB studies appear to have been conducted in general accordance with common laboratory practice. While areas of uncertainty were noted, no significant errors were identified in either study that would have materially compromised the quality of the data or substantially changed the magnitude of the reported results. Apparently, the high school students working with PANNA had no experience or training with this type of testing prior to collecting the samples in Hastings. However, the students were reportedly trained and tested by qualified scientists experienced with such air analysis.

PANNA used a modified U.S. National Institute for Occupational Safety and Health (NIOSH) Method 5600 in which samples were collected using a “drift catcher” device on which chemicals absorbed onto a XAD-2 resin. Samples were quantified using gas chromatography with electron capture detection (GC/ECD) and were qualitatively confirmed with ion trap mass spectrometry (GC/MS). It is not clear why the confirmatory results were not quantified in the PANNA report. Page 32 of the PANNA report states that, “Samples that were initially determined to contain analyte in amounts less than the LOQ for the initial method were reanalyzed using a more sensitive method with a lower LOQ.” Since results for both primary and confirmatory analysis were not presented, there is no way to compare these results to determine whether the higher or lower value was reported, or to what extent analytical interference may have resulted in artificially elevated levels in the report. No overt errors or unacceptable quality control problems were noted in the data that was provided in the PANNA report.

For the SJCSB report, diazinon in air was tested using NIOSH Method 5600, which utilizes an OVS-2 collection tube with 13 mm quartz filter and XAD-2 resin. Samples were analyzed on a gas chromatograph with flame photometric detection GC/FPD (NIOSH, 1994). Endosulfan was tested in air by U.S. Occupational Safety and Health Administration (OSHA) Method 2023. This method employs the same collection apparatus as NIOSH Method 5600, but utilizes gas chromatography with electron capture detection (OSHA, 1988). Trifluralin was tested in air using Monsanto Proprietary Method #33, which involved the use of GC/ECD instrumentation. A blank sample was analyzed with each of the samples, demonstrating that there was no cross-contamination. One potentially significant deficiency in the SJCSB data is that no laboratory control sample (*e.g.*, laboratory spikes) data was presented with the air samples, and therefore it is not possible to determine whether sample recoveries were within acceptable ranges for this data set. The SJCSB report states, “Unless otherwise noted below, all quality control results associated with this sample set were within acceptable limits and/or do not adversely affect the reported results.” Without further information, FDACS has no way to determine whether this issue compromises the quality of that data. Although no confirmatory data was presented (*e.g.*, dual column, mass spectrometry analysis), the need for confirmation was not apparent since there were no pesticides detected in any of the air samples in the primary analysis.

Three soil samples were collected by SJCSB. Diazinon in soil was tested using USEPA Method 8141A. Endosulfan (Endosulfan I, Endosulfan II, and Endosulfan sulfate) and trifluralin were tested using USEPA Method 8081A. Soil samples appear to have been prepared and analyzed within established hold times, and in general, quality assurance and control measures appear to have been within the established acceptable limits.

C. Analytical Chemistry Results

No endosulfan or diazinon degradation products (*i.e.*, endosulfan sulfate, diazoxon) were detected in the PANNA air samples. The following table summarizes the range of detections for each analyte in the PANNA study:

Table 4
PANNA Study Air Monitoring Results

Pesticide	Minimum (ng/m^3)	Maximum (ng/m^3)	Average (ng/m^3)
Diazinon	N.D.	897	311
Endosulfan	45	626	278
Trifluralin	N.D.	376	84

N.D.- Not detected above method minimum detection limit

The SJCSB study reported no detectable levels of any pesticides in the air inside of the school or in the outdoor air on the school property. Trace levels of endosulfan and diazinon, but not trifluralin, were detected in the soil at the school at levels well below the respective Florida Department of Environmental Protection Soil Cleanup Target Levels for residential areas, which are considered to be acceptable levels for children.

Table 5
SJCSB Study Air Monitoring Results

Pesticide	Minimum	Maximum	Average
Indoor Air			
Diazinon	N.D.	N.A.	N.A.
Endosulfan	N.D.	N.A.	N.A.
Trifluralin	N.D.	N.A.	N.A.
Outdoor Air			
Diazinon	N.D.	N.A.	N.A.
Endosulfan	N.D.	N.A.	N.A.
Trifluralin	N.D.	N.A.	N.A.
Soil			
Diazinon	N.D.	0.0032*	0.0023
Endosulfan	0.0015	0.0096	0.0050
Trifluralin	N.D.	N.D.	N.A.

N.D.- Not detected above method minimum detection limit (MDL).
The calculated avg. uses ½ the detection limit for N.D. results.
N.A.- Not applicable
Air concentrations expressed in ng/m^3
Soil concentrations expressed in mg/kg

Endosulfan is the sum of endosulfan I, II, and endosulfan sulfate.

The Florida Soil Cleanup Target Levels (SCTLs) for residential areas are 450 mg/kg for endosulfan and 70 mg/kg for diazinon. There is no SCTL for trifluralin.

*- Estimated- Detected below reporting limit

D. Conclusions Reached by the Two Studies

The PANNA report concluded that endosulfan and diazinon, but not trifluralin, were present in air near the school at levels posing potential health risks to infants one year old or less, and in some cases there were reported risks to older children, pregnant mothers, and other adults. The PANNA conclusion is based on a comparison of the maximum values detected to the PANNA-derived comparison values, called Reference Exposure Levels (RELs).

Table 6
PANNA Health-Based Comparison Values vs. Detected Levels

Pesticide	PANNA REL* (ng/m^3)	Avg. (Max.) Detected (ng/m^3)
Endosulfan	339	278 (626)
Diazinon	145	311 (897)

* The Health-Based Comparison Value is a Reference Exposure Level (REL) derived by PANNA. The PANNA REL is not a USEPA standard or guideline value. Trifluralin is not included in the table, since PANNA concluded that detected levels were sufficiently low as to cause no health concern based on their calculation for chronic exposure.

The SJCSB report concluded that there is negligible health risk to children and adults at the school. The SJCSB conclusion is based on their finding that the air both inside the school building and outside of the school contained no detectable concentration of pesticides. While they did detect diazinon and endosulfan in soil, but not trifluralin, the levels at which the pesticides were detected were many times less than the Florida Soil Cleanup Target Levels for these compounds in residential areas.

Table 7
SJCSB Health-Based Comparison Values vs. Detected Levels

Pesticide	Occupational Threshold Values* (ng/m^3)	Levels Detected (ng/m^3)
Endosulfan	100,000	<3,300
Diazinon	100,000	<2,100

*The SJCSB used OSHA and NIOSH occupational thresholds as health-based comparison values, which are placed by both agencies at 100,000 ng/m^3 for both endosulfan and diazinon. There are no current occupational threshold values for trifluralin. No pesticides were detected in air in the SJCSB study above the indicated levels.

The PANNA RELs were incorrectly referred to in news articles as USEPA air quality standards. Newspaper accounts reported that levels of pesticides in air near the school in Hastings exceeded the “highest acceptable level given by the Environmental Protection Agency…”. When PANNA subsequently submitted a newspaper opinion piece entitled, “Pesticide Results at South Woods Elementary- ‘Safe’ or Suspect?”, they stated the following: “Because the US Environmental Protection Agency (EPA) has designated levels of concern that are several hundred nanograms per cubic meter of air for two of the pesticides in question, no conclusion can be drawn from the MACTEC study about how ‘safe’ the air is” (PANNA, 2007).

The USEPA has not at this time adopted any air standards for these pesticides. Moreover, the USEPA has not designated "levels of concern" for these compounds at the levels indicated by PANNA, and such statements could easily be misconstrued to imply that the Agency would have also concluded that a human health concern exists at the school in Hastings. The USEPA has not yet made any formal determinations regarding potential risks in this case. In cases where the Agency has developed provisional inhalation reference concentrations (RfCs) or comparable screening values for these pesticides representing levels of no concern for chronically exposed children and adults, the levels are several thousands of nanograms per cubic meter, well above maximum concentrations detected by PANNA.

The PANNA conclusion that there is a significant risk of adverse health effects in Hastings rests on the assumptions used by PANNA to derive their REL comparison values. Specifically, the REL value that PANNA calculated assumes an improbable exposure scenario in which an infant or young child would be outdoors continuously next to the agricultural field for 24 hours.

Even though pesticides were not detected in all of the PANNA study samples, PANNA concluded that the high frequency of detection of pesticides in the air was cause for concern. However, detection of a pesticide in air, even in a large proportion of the samples, does not mean that there is necessarily a corresponding elevated health risk. Modern analytical chemistry technology often permits the detection of substances at extremely small levels (*e.g.*, parts per trillion) that are often many orders of magnitude less than concentrations associated with health risks. Given these sensitive detection capabilities, it is understandable that residues of these pesticides would be found in air samples next to an agricultural field. Despite the high frequency of trifluralin detections, PANNA concluded that trifluralin did not pose any health concerns at the levels found. It is also noteworthy that despite different analytical sensitivities of the testing apparatuses used in the PANNA and SJCSB studies, minimum detection limits were consistently achieved in both studies at levels that are well below their respectively chosen health-based comparison values.

The SJCSB report concluded that none of the tested pesticides were at levels of concern either indoors or outside of the school, or in soil on the school property. Since no pesticide residues were detected in the air samples, that conclusion was based on a comparison of the method detection limit (MDL) with occupational thresholds. Occupational thresholds represent levels that protect the health of adult workers exposed at that level for 40 hours per week over a working lifetime (NIOSH, 1995a; NIOSH, 1995b). Although occupational thresholds have some margin of safety built into their derivation, they are designed to protect healthy, working adults, and therefore they may not necessarily be adequate for the protection of children in all cases. Nevertheless, occupational threshold levels have sometimes been used by authoritative bodies at various times in risk assessments involving non-occupational settings, such as residential communities, when more appropriate comparison values were not available (CDPR, 1995). Depending on the particular situation, occupational threshold values may be safe levels for children, as they are often set at lower levels than the short term exposure guidelines (*e.g.*, AEGLs, EEGLs, TEELs) sometimes used by the USEPA and other bodies in their risk assessments involving both adults and children (ATSDR, 2003). In some cases, occupational threshold values are divided by a factor of 10 to account for the potential increased sensitivity of children and sensitive adults, as was done in at least one assessment evaluating the exposure of children to spray drift from an agricultural field (ATSDR, 2003). Occupational threshold values for both endosulfan and diazinon have been set at 100,000 ng/m^3 (NIOSH, 1995a; NIOSH, 1995b); dividing this value by an uncertainty factor of 10 to account for the potential for increased sensitivity in children would result in an acceptable level of 10,000 ng/m^3. In the case of the SJCSB report, the levels at which the pesticides were not detected (*i.e.*, the MDL) were one to two orders of magnitude less than the occupational thresholds, and all were also well below the occupational threshold values when they were divided by an additional uncertainty factor of ten. The maximum levels detected by PANNA are much lower than the laboratory's levels of detection noted by the SJCSB.

III. Human Health Risk Assessment

Numerous human epidemiological studies and toxicological studies using laboratory animals have been conducted on the specific compounds addressed by the PANNA and SJCSB reports. A comprehensive analysis of the studies in the scientific literature for these compounds is beyond the scope of this report. The reader is directed to the following documents providing robust evaluations and summaries of the available toxicological information for these compounds: ATSDR, 2006; ATSDR, 2001; ATSDR, 2000; USEPA, 2002a; USEPA, 2002b; USEPA, 2000a; USEPA, 1996; HSDB, 2007; WHO, 2004; WHO, 2001; WHO, 1998; INCHEM, 1994; ChemID Plus, 2007; ICPS, 2002; EXTOXNET, 2007; EXTOXNET, 1993; ITER, 2007; NIOSH, 1995a; NIOSH, 1995b; NPIC, 1998; U.S. Department of Defense, 2001; and APVMA, 2006.

The USEPA has concluded that the pesticide active ingredients considered in this report are acceptable for use on food consumed by the general public, including infants and pregnant women, provided that the pesticides are used as directed on the product label and that established tolerance levels (permitted levels of pesticides on food) are not exceeded. In general, federal agencies such as the USEPA and the ATSDR typically base conclusions regarding the safety of pesticide active ingredients and the establishment of regulatory or guideline levels for these on the lowest concentration causing an adverse health effect in the most sensitive animal species tested. Laboratory animals used in the toxicological studies are specifically bred to enhance their susceptibility to adverse chemical effects. While this approach is conservative, it is likely to bias the results toward false positive developmental findings (Barlow et al., 2002). On the other hand, for some chemicals, humans appear to be more toxicologically sensitive than the test animals (Schardein and Keller, 1989). Even so, humans are almost never expected to encounter the high levels used in these animal studies, and therefore the relevance of animal studies must be interpreted with caution.

The risk of an adverse effect of a chemical depends both on the toxicity of the chemical (*i.e.*, hazard identification) and the amount (*i.e.*, exposure assessment) to which a person is exposed (Faustman and Omenn, 2003). The amount of pesticide active ingredient in a given formulation, the application rate, and the application frequency are examples of factors affecting potential exposure to a pesticide. In addition, exposure through inhalation is affected by the pesticide's volatility and persistence under specific environmental conditions.

Like numerous other natural and synthetic chemicals, some pesticide compounds may be capable of traveling long distances through the air by way of volatilization or bound to particulate matter. These processes depend on how quickly the compound degrades in the environment and on the compound's physical and chemical properties governing the partitioning between air and different environmental matrices (*e.g.*, water, plant surfaces and soil). The magnitude and duration of post-application pesticide volatilization is affected by soil moisture, temperature, precipitation events, and organic carbon content in the soil. Agricultural and environmental management practices can also influence the environmental fate of pesticides and other agrichemicals, which in turn affect the levels and length of time to which people may be exposed to these substances (Hapeman et al., 2006; McConnell, 2005).

Appendices A, B, and C of this report present results from studies reporting levels of endosulfan, diazinon, and trifluralin that have been measured in various environments such as agricultural areas, outdoor background air far removed from use areas, and indoor environments. The intent is both to illustrate the ways in which these pesticide compounds behave in various environmental settings, and also to view the levels found in Hastings in a broader context when compared to typical exposure levels that have been reported in other studies.

The duration of exposure is critical to any inhalation exposure assessment. One reason different federal regulations or guideline values differ is because they are designed to protect people exposed for different amounts of time (ATSDR, 2006). Higher exposure levels may generally be tolerated over short periods of time with little affect, whereas continuous or chronic exposure to the same level in some cases may lead to more serious health effects. In general, the shorter the duration of exposure, the higher the acceptable concentration in air is likely to be, although this depends to a certain extent on the toxicological and physical properties of the specific chemical.

If the assessment is examining chronic or continuous levels to which a population may be exposed in ambient air, it is appropriate to determine what the average levels are in air over many weeks or months. For such prolonged exposure scenarios, the acceptable exposure levels are generally much lower than scenarios which are one-time events, short-term or intermittent types of exposures.

In the case of the pesticides reported in the air near the school, the exposure scenario is probably neither acute nor chronic. While an hour or two of exposure on a playground would be considered to be an acute exposure, if it is assumed that this exposure takes place periodically throughout the school year, then the potential exposures are intermittent and of intermediate duration. Therefore, using a health-based comparison value such as a USEPA reference concentration or comparable USEPA ambient air screening value, which represents a level at which children or other potentially sensitive individuals can be chronically or continuously exposed over a lifetime with little or no risk of experiencing any adverse health effects, would be conservative and highly protective when used in a risk assessment in which only intermittent exposures of intermediate duration are expected (USEPA, 2006a).

A. Health-based Comparison Values

Government agencies charged with the protection of public health, such as the USEPA, and the ATSDR, have developed comparison values to which levels measured in the environment can be compared in order to determine whether potential health concerns are posed by a given chemical. These comparison values are designed to represent exposure levels presenting a negligible health risk, although they are often misconstrued as being rigid threshold limits above which toxicity is likely to occur (Risher and DeRosa, 1997). Although different authoritative bodies may differ in selecting certain variables or assumptions in deriving a health-based comparison value (Risher and DeRosa, 1997; Selene et al., 1998), the overall approach is generally similar among the different agencies, and is described below.

The first steps are to: (1) identify the exposure scenario for which one is looking to establish a guidance level (*e.g.*, residential, occupational, dietary, *etc.*), and based on that information, (2) identify the toxicity studies that are applicable to that scenario (*e.g.*, a 21-day dermal, developmental toxicity, chronic toxicity study, *etc.*). After identifying the appropriate study, the No Observed Adverse Effect Level (NOAEL) from that study will serve as the basis for the comparison value. The NOAEL value is the highest dose tested in a toxicity study that did not elicit a response in the test animal. In cases where a NOAEL was not established, regulators may use a Lowest Observed Adverse Effect Level (LOAEL). Once the appropriate NOAEL or LOAEL is identified, uncertainty factors (*i.e.*, safety factors) are applied by dividing the NOAEL or LOAEL by the combined product of all of the uncertainty factors.

This process generally results in an acceptable health-based comparison value of 100 to 1,000 times less than a dose that caused no adverse effect in the animal study, if a NOAEL was used. Depending on the quality of the data, however, the actual uncertainty factors may be increased or decreased. Unless there is sufficient evidence to the contrary, these uncertainty factors assume that humans are about ten times more sensitive than the most sensitive animal species tested, and that some individuals are about ten times more sensitive than the general public. Additional safety factors may also be added if a LOAEL is used instead of a NOAEL, if the effects from one route of administration are extrapolated to another (*e.g.*, oral ingestion to inhalation), or if a specific population (*i.e.*, children, pregnant women) appears to be more sensitive or at greater risk. When comparing the various health-based values for a given compound that have been derived by different authoritative bodies, it is crucial to consider the severity of effect for each toxicological endpoint selected in addition to the extent to which the various uncertainty factors are applied.

The USEPA has not developed legally enforceable health-based regulatory *standards* for pesticides in air, although in some cases the Agency has derived health-based *guidance* concentrations, such as inhalation reference concentrations. A number of alternative health-based comparison values for these pesticides have been produced by federal agencies or other authoritative bodies, but none of these comparison values are enforceable standards, except for those issued by OSHA in the occupational setting. Although OSHA planned on adopting values for diazinon and endosulfan in 1989 at 0.1 mg/m^3 (100,000 ng/m^3) based on consideration of NIOSH and ACGIH values set at this level for these compounds, the OSHA permissible exposure levels were vacated by a federal judge and are therefore not legally enforceable (HSDB, 2007; NIOSH, 1995a; NIOSH, 1995b).

Both the PANNA report and the SJCSB report each presented only one type of health-based comparison value: 1) PANNA calculated REL values; and 2) SJCSB used occupational threshold values (*i.e.*, OSHA, NIOSH, or ACGIH values) as comparison values. PANNA followed the general approach outlined above in formulating their REL values, although there was significant departure from commonly accepted practice in other aspects of their derivation, most notably in their use of a scenario in which a one-year old infant is placed outdoors next to the agricultural field over 24-hours while continuously exposed to the maximum concentration of pesticides detected in air. That scenario is not representative of the situation at the school in Hastings, and is likely to overestimate the actual risk. Similarly, the use of the adult worker exposure scenario in the SJCSB study also does not apply to the children at the school in Hastings, and use of occupational threshold values as comparison values for the children will likely underestimate their risk.

PANNA RELs

News articles indicated that the PANNA REL comparison values are equivalent to USEPA regulatory values. However, the PANNA report states (page 6) that the RELs are *calculated from* the USEPA's inhalation No Observed Adverse Effect Level (NOAEL). The PANNA report did not reference documentation that would indicate that the Agency considers the PANNA REL values to be valid risk-based comparison values. The USEPA has not sanctioned the use of PANNA RELs for inhalation risk assessments. Rather, the Agency indicated that use of the PANNA RELs would overestimate the risks involved at the school and that practices used by PANNA and some other advocacy groups tend to exaggerate exposure and risk. The USEPA has indicated that use of a 24–hour inhalation exposure period would overestimate exposure and subsequent risk in cases in which there is less than 24-hour exposure. Often, volatilization exposures peak in a relatively narrow time window that is significantly shorter than 24 hours. Also, the USEPA has indicated that sampling air in an outdoor location just a few feet from the field overestimates exposure and risk because it is unlikely that any individual would remain stationary outdoors in such a location for a 24–hour period. Furthermore, the USEPA reference concentration methodology differs from the PANNA's REL approach by taking into consideration of the anatomical, physiological, and kinetic differences between test animals and humans, whereas PANNA's approach assumes that the body weight and breathing rate alone affects dosimetry (USEPA, 2005; USEPA, 2006b; USEPA/personal correspondence, 2007; USEPA, 1994).

PANNA states on page 7, "Exceedances of the RELs for diazinon and endosulfan are not necessarily anticipated to cause the symptoms of acute poisoning described above; however, the REL does represent a level of concern for inhalation exposure analogous to US EPA's Reference Dose for dietary exposure." If the REL is analogous to the USEPA reference dose, it does not represent a "level of concern," but rather a level at which exposure is considered to be acceptable.

The PANNA report states that, “Concentrations below the REL do not necessarily indicate that the air is ‘safe’ to breathe. In particular, a number of recent studies evaluating the capacity of different people to metabolize toxic substances show that the variability among different people can be substantially greater than the variability assumed by U.S. EPA in its toxicological analysis. In addition, on all but one day, all three pesticides were found in samples above detection limits.” While it is true that there are differences between individuals, the USEPA typically assigns a protective uncertainty factor of ten to account for this, which is on average greater than the actual differences measured between people (Dourson et al., 2002). It is also true that in some cases, as suggested by PANNA, studies have reported much greater than 10X differences between people. For example, the extent to which specific organophosphate metabolizing enzymes break down organophosphate pesticides in some people may differ greatly. However, in humans, such differences are usually greatly reduced after considering that not one, but many enzymes present in humans are known to break down organophosphate compounds. Moreover, as PANNA points out on page 33 of its report, there are numerous other uncertainty factors (each up to 10X) that are applied to the USEPA risk assessment calculations in addition to the 10X uncertainty factor for individual differences. Given the multiple layers of safety factors, a level of exposure deemed acceptable by the USEPA is likely to be many times (*i.e.*, orders of magnitude) less than levels that are likely to cause people actual harm. In the rare instance in which one uncertainty factor may be insufficient, the cumulative uncertainty factor and other conservative assumptions used in the risk assessment are designed to be protective of human health.

Occupational Threshold Values used by SJCSB

MACTEC, the consultant to SJCSB, collected air samples at the school and reported no detectable concentrations of these pesticides. MACTEC compared the MDL of the method to applicable occupational threshold values (*i.e.,* OSHA Permissible Exposure Levels; NIOSH Recommended Exposure Levels), which are significantly higher than PANNA’s REL values. The SJCSB method detection limits at which no pesticides were found are far less than the occupational threshold health based comparison values. Even if the occupational threshold comparison values are reduced by an additional 10X safety factor (as is typically used by the USEPA to account for additional sensitivity in children), the detection limit levels at which no pesticides were found remain well below that level.

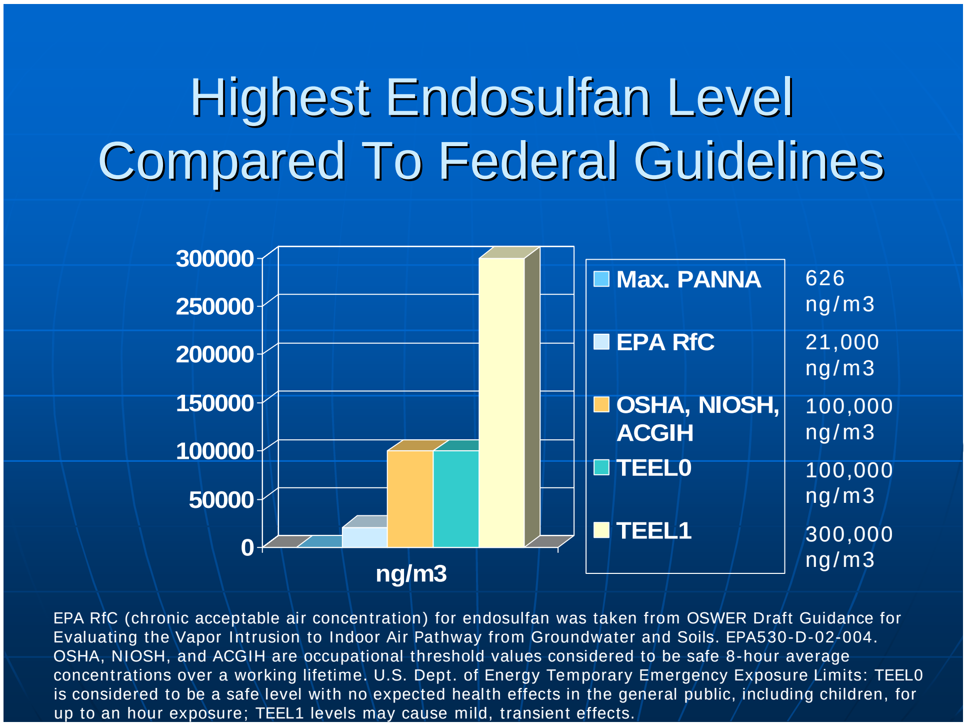
Occupational threshold values represent levels to which workers may be exposed 40 hours per week over a working lifetime without any appreciable health risk. This is similar to the amount of time a child would typically spend at school. However, occupational threshold values are not generally considered to be the best comparison values for the general population, since they are designed to protect relatively healthy working adults, but do not consider developmental effects or the protection of children or other potentially sensitive individuals. However, occupational threshold values do not necessarily represent unsafe levels for children, as children are not always more sensitive, and are in some cases even less sensitive than adults to the toxic effects of a given substance. As such, occupational threshold values at times have been used as points of comparison in evaluations of pesticides in ambient outdoor air by various governmental agencies.

Alternative Health-based Comparison Values Not Considered by PANNA or SJCSB

Since other comparison values are available for these compounds beyond those used by PANNA and SJCSB, the alternate values are presented in this report to provide additional points of reference to which the reported detections and comparison values can be compared. This comparison is important for the following reasons: (1) occupational threshold values do not necessarily apply directly to children or to the exposure durations expected to occur outside of the school in Hastings; (2) these values put into context the levels detected by PANNA, as well as the levels not detected in the SJCSB study; and (3) the alternate health-based comparison values can be compared to various levels of these pesticides that have been found in air in other studies available in the scientific literature.

The following bar graphs (Figures 1 through 3) illustrate the maximum levels of pesticides detected in the air by PANNA in Hastings and contrast these levels to various health-based comparison values that have been established by various authoritative bodies, such as the USEPA, the U.S. Public Health Service, and the U.S. Department of Energy:

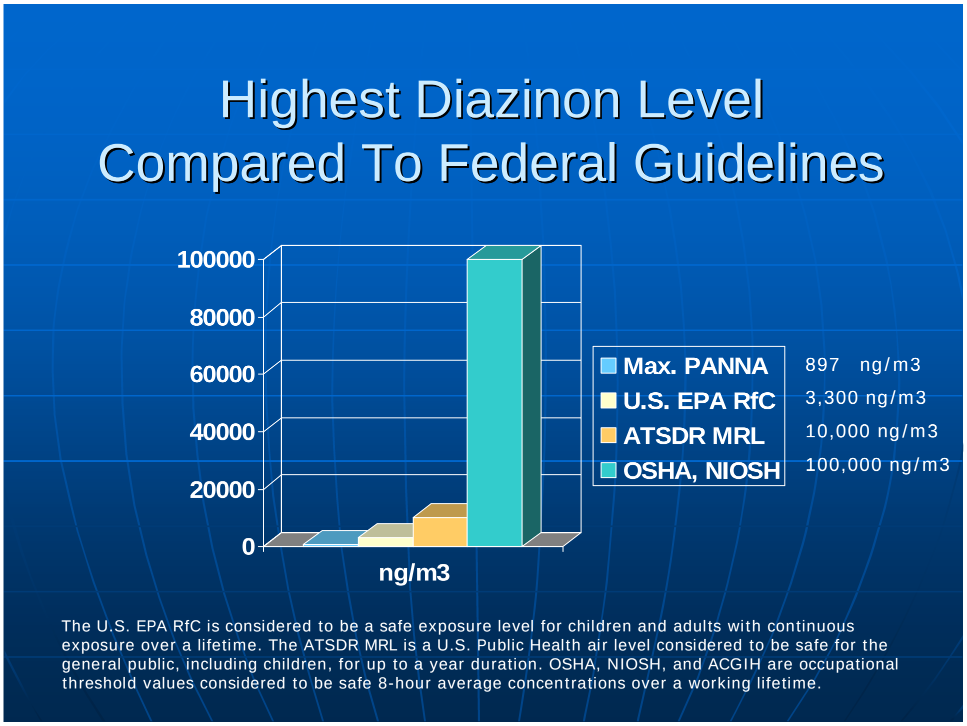
Figure 1



Highest Endosulfan Level Compared To Federal Guidelines

EPA RfC (chronic acceptable air concentration) for endosulfan was taken from OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils. EPA530-D-02-004. OSHA, NIOSH, and ACGIH are occupational threshold values considered to be safe 8-hour average concentrations over a working lifetime. U.S. Dept. of Energy Temporary Emergency Exposure Limits: TEEL0 is considered to be a safe level with no expected health effects in the general public, including children, for up to an hour exposure; TEEL1 levels may cause mild, transient effects.

Figure 2

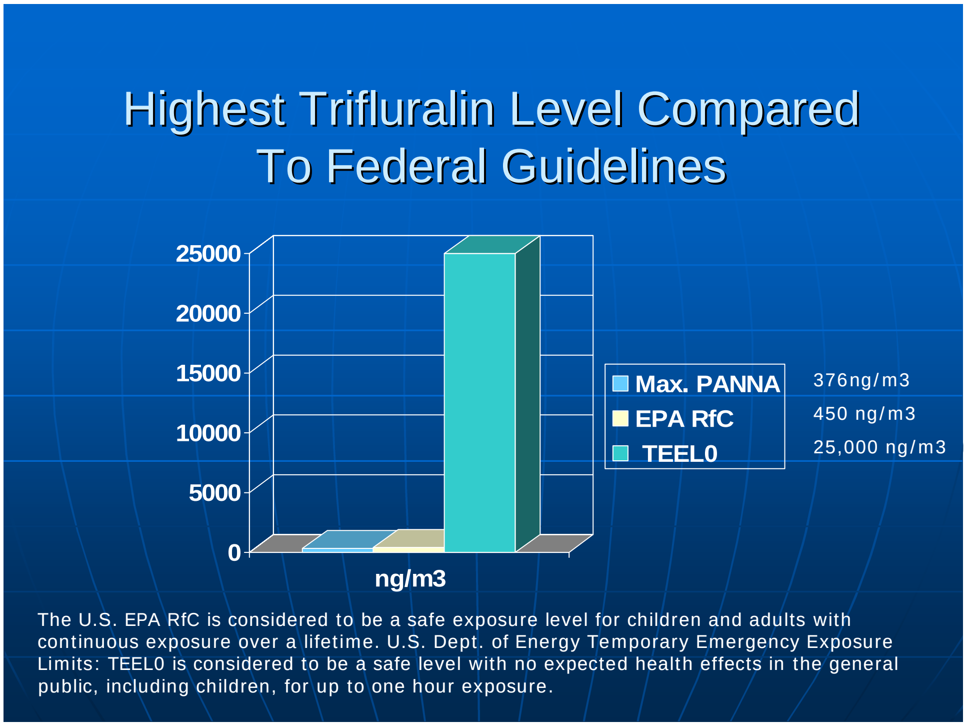


Highest Diazinon Level Compared To Federal Guidelines

🟦 Max. PANNA	897 ng/m3
🟨 U.S. EPA RfC	3,300 ng/m3
🟧 ATSDR MRL	10,000 ng/m3
🟩 OSHA, NIOSH	100,000 ng/m3

The U.S. EPA RfC is considered to be a safe exposure level for children and adults with continuous exposure over a lifetime. The ATSDR MRL is a U.S. Public Health air level considered to be safe for the general public, including children, for up to a year duration. OSHA, NIOSH, and ACGIH are occupational threshold values considered to be safe 8-hour average concentrations over a working lifetime.

Figure 3



Highest Trifluralin Level Compared To Federal Guidelines

🟦 Max. PANNA	376ng/m3
🟨 EPA RfC	450 ng/m3
🟩 TEEL0	25,000 ng/m3

The U.S. EPA RfC is considered to be a safe exposure level for children and adults with continuous exposure over a lifetime. U.S. Dept. of Energy Temporary Emergency Exposure Limits: TEEL0 is considered to be a safe level with no expected health effects in the general public, including children, for up to one hour exposure.

USEPA Inhalation Reference Concentrations (RfCs)

An RfC is defined by the USEPA as follows:

> "An estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. It can be derived from a NOAEL, LOAEL, or benchmark concentration, with uncertainty factors generally applied to reflect limitations of the data used. Generally used in EPA's noncancer health assessments" (USEPA, 2007a).

The rationale and methods for which inhalation reference concentrations are developed by the Agency are described in a number of publicly available documents (USEPA, 2006a; USEPA, 2006b; USEPA, 2002c; USEPA, 1994; USEPA, 2004a). Although the USEPA reference concentrations represents acceptable chronic exposure concentrations, and are therefore acceptable for acute exposures, the Agency has recently recognized the need to develop inhalation reference concentrations for acute and other "less-than-lifetime" exposure durations (USEPA, 2006c; USEPA, 2006d; Woodall, 2005; USEPA, 2002c; Sigethy et al., 1994).

The USEPA's Integrated Risk Information System (IRIS) is a high-quality, peer reviewed, and frequently updated chemical toxicity information source, and is the EPA's official repository of Agency-wide consensus chronic human health toxicity information and toxicity values, such as the RfC (USEPA, 2006e; USEPA, 2004a). While none of the three pesticide compounds at issue in this report have RfC values entered into the USEPA IRIS system, the USEPA has in fact developed provisional chronic ambient air inhalation RfCs or comparable screening values that are applicable to all of these compounds (*e.g.*, USEPA Region 3 Risk-Based Concentrations, USEPA Region 6 Human Health Medium Specific Screening Levels, and USEPA Region 9 Preliminary Remediation Goals for ambient air). These are considered to be surrogate comparison concentrations that are used by various regional offices within the USEPA in the absence of Agency-wide RfCs that are derived using RfC methodology developed by the USEPA's Office Research and Development. However, these provisional USEPA health-based comparison concentrations are nonetheless considered by the USEPA to protect human health over long-term exposure durations.

The inhalation route represents only about one percent of the total exposure for most scenarios assessed by the USEPA Office of Pesticide Programs (OPP). Inhalation exposure risk estimates are based on air sampling data that do not differentiate between gases and particles, or between different particle sizes. Estimates for children use breathing rate and exposure duration assumptions that are derived from the EPA Exposure Factors Handbook and other published sources. OPP typically uses higher-end values for input variables (*e.g.*, breathing rates, application rates) in short-term scenarios and average or more typical values for intermediate-term or chronic scenarios. OPP calculates and reports childhood risks separately from adult risks (USEPA, 2003a).

ATSDR MRL (Minimum Risk Level)

The Agency for Toxic Substances and Disease Registry (ATSDR), a branch of the U.S. Department of Health and Human Services, has developed guidance health-based comparison values called Minimal Risk Levels (MRLs). The ATSDR MRL represents an amount of a hazardous substance to which people may be exposed for 24-hours per day over a specified number of days that is likely to be without appreciable risk of adverse non-carcinogenic health effects, even among the most sensitive and vulnerable portions of the population, such as infants. The ATSDR has established inhalation MRLs for acute (1-14 days), intermediate (15-364 days), and chronic (365 days and longer) exposure durations. MRLs are generally based on the most sensitive chemically-induced health endpoint considered to be relevant to humans. MRLs are based on less serious health effects that occur at low levels, and are never based on more serious health endpoints occurring at much higher levels (*e.g.*, irreparable damage to the liver or kidneys, or birth defects). MRLs are screening values only and do not represent adverse health effect levels. If any chemical exceeds its MRL at a given site, a more refined exposure and risk assessment should be conducted in order to more precisely define the potential risk. Using an approach similar to that used by the USEPA health-based inhalation reference concentrations (RfCs) and oral reference doses (RfDs), MRLs are derived by dividing the appropriate health endpoint by various uncertainty factors (*i.e.*, safety factors). MRLs are typically up to one-hundred to a thousand times less than the lowest dose causing minimal, non-serious health effects(s) observed in the most sensitive animals tested. Exposures to substances at doses above MRLs will not necessarily cause adverse health effects but should be further evaluated. MRLs are intended to serve only as a screening tool and are not intended to define cleanup or action levels (ATSDR, 2006; ATSDR, 2005; USEPA, 2002c; Pohl and Abadin, 1995; DeRosa et al., 1998; Selene et al., 1998).

U.S. Department of Energy TEELs

The U.S. Department of Energy Temporary Emergency Exposure Limit (TEEL) is another type of comparison value, with values available for both endosulfan and trifluralin (U.S. DOE, 2007a; U.S. DOE, 2007b; U.S. DOE, 2007c; U.S. DOE, 2004; NOAA, 2007; EMI SIG, 2007a). TEELs represent levels estimated to protect the general public from adverse health effects resulting from relatively short exposure durations such as accidental chemical releases. TEELs are considered by the USEPA to be approximate health-based values and are not generally used by the Agency as the basis of regulatory decision-making, although TEELs are sometimes used in Agency risk assessments as appropriate comparison values in different (*i.e.*, non-emergency) types of situations where better comparison values are not readily available (USEPA, 2006e). The different types of TEELs are defined by the Department of Energy as follows:

TEEL-0 The threshold concentration below which most people will experience no appreciable risk of health effects;
TEEL-1 The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor;

TEEL-2 The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action;
TEEL-3 The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

Although the TEEL definitions do not explicitly indicate specific allowable exposure durations, the definitions for the TEEL1, TEEL2 and TEEL3 are for all practical purposes considered to be identical to the Emergency Response Planning Guidelines (ERPGs) developed by the American Industrial Hygiene Association (AIHA), which are comparison values also used at times by the U.S. Department of Energy, the USEPA, and other agencies. TEELs are substituted for ERPG values when ERPG values do not exist for a given chemical. ERPG values, and thus TEELs, are considered to be acceptable exposure levels for one hour duration (ATSDR, 2003).

While TEEL values do not incorporate in their derivation the same level of conservatism that is utilized in the derivations of USEPA reference concentrations and ATSDR MRLs (which are based on continuous or chronic exposure scenarios and make use of various uncertainty factors), the TEELs nevertheless represent levels that should not present imminent health risks to the general population over relatively short exposure durations. On the other hand, USEPA reference concentrations and MRLs are based on continuous and chronic exposures, and are likely to overestimate the risk in most situations in which there is only intermittent exposure.

USEPA Prioritization of Health-based Comparison Values

The USEPA Air Toxics Website indicates that the USEPA Technology Transfer Network collects hazard identification and dose-response assessment information from various sources, and prioritizes the information for the purpose of conducting risk assessments for substances in air according to (1) conceptual consistency with EPA risk assessment guidelines and (2) the level of review received. The USEPA uses the following hierarchy in selecting comparison values for **chronic** inhalation exposure scenarios (USEPA, 2006f; USEPA, 2006e; USEPA, 1999a):

1. **RfC**s (Inhalation Reference Concentrations, derived by the USEPA)
2. **MRL**s (Minimum Risk Levels, derived by the Agency for Toxic Substances and Disease Registry of the U.S. Public Health Service)
3. **REL**s (Reference Exposure Levels, Chronic Inhalation, derived by the California Environmental Protection Agency).

The various comparison values for **acute** inhalation exposure scenarios, which may include exposure durations from a few minutes to in some cases up to two weeks, are prioritized by the Agency as follows (USEPA, 2006e):

1. **AEGL**s (Acute Exposure Guideline Levels, derived by the National Research Council)
2. **ERPG**s (Emergency Response Planning Guidelines, derived by the American Industrial Hygiene Association)
3. **MRL**s (Minimum Risk Levels, derived by the Agency for Toxic Substances and Disease Registry of the U.S. Public Health Service)

4. **REL**s (Reference Exposure Levels, Acute Inhalation, derived by the California Environmental Protection Agency)
5. **IDLH/ 10** (Immediately Dangerous to Life or Health level divided by 10, derived by the National Institute for Occupational Safety and Health)
6. **TEEL**s (Temporary Emergency Exposure Limits, derived by the U.S. Dept. of Energy)

It should be noted that the California EPA REL is not the same as the PANNA REL or the NIOSH REL values. The USEPA has stated, "The CalEPA reference exposure level is a concentration at or below which adverse health effects are not likely to occur. It is not a direct estimator of risk, but rather a reference point to gauge the potential effects. At lifetime exposures increasingly greater than the reference exposure level, the potential for adverse health effects increases" (USEPA, 2000b).

For the compounds of interest in this report, official AEGL, ERPG, IDLH, or CalEPA RELs (acute or chronic), were not identified (USEPA, 2006e; NIOSH, 2007; CalEPA, 2007). However, for one or more of the compounds of interest, RfC, MRL, and TEEL comparison values were located. The following paragraphs discuss the specific types of health-based comparison values that were found for the compounds of interest:

ENDOSULFAN HEALTH-BASED COMPARISON VALUES

The maximum endosulfan value of **626 ng/m^3** reported by PANNA was less than all of the available acute and chronic health-based comparison values. For endosulfan, one of the alternate health-based comparison values is a provisional USEPA inhalation reference concentration (RfC) of **21,000 ng/m^3**. The RfC used in the USEPA reports was reportedly derived from the oral reference dose (RfD) listed in the USEPA IRIS database. This RfC value was used as the basis for calculating endosulfan inhalation risk in several USEPA reports (USEPA, 2006g; USEPA, 2004b; USEPA, 2002d). Furthermore, a similar, but slightly higher chronic exposure screening value for endosulfan in ambient air of **22,000 ng/m^3** is used by USEPA Regions 3, 6 and 9 in their risk assessments (USEPA, 2007b; USEPA, 2007c; USEPA, 2004c). Use of these values for acute or subchronic exposure scenarios should be highly protective, since the inhalation reference concentration is considered to be an acceptable level even with continuous, long-term exposure.

For endosulfan, the TEEL values are as follows:
TEEL-0: 100,000 ng/m^3
TEEL-1: 300,000 ng/m^3
TEEL-2: 800,000 ng/m^3
TEEL-3: 35,000,000 ng/m^3

Calculating Acceptable Exposure Level for Endosulfan Using the USEPA Margin of Exposure Approach

The USEPA typically calculates risks using a concept called a "Margin of Exposure" (MOE). If the USEPA equation for calculating the MOE is used to calculate the inhalation risk to a one-year-old child playing at the school, assuming that the maximum concentration of endosulfan reported by PANNA is present in the air for a realistic 2-hour duration, and using the NOAEL of 0.2 mg/kg/day used by the USEPA in its risk assessment for endosulfan, there is no unacceptable risk:

> MOE = NOAEL/inhalation dose.
>
> NOAEL = 0.194 mg/kg/day, based on a 21-day rat inhalation study used by the USEPA in its risk assessment for endosulfan. (The LOAEL was determined to be 0.387 mg/kg/day, based on decreased body-weight gain, decreased leukocyte counts in male rats and increased creatinine values in the female rats).
>
> Inhalation Dose (mg/kg/day) = {air concentration (μg/m^3)* inhalation rate (m^3/hr)*0.001 mg/μg*2 hours}/ body weight (kg).
>
> Inserting the highest detected endosulfan value of 0.626 μg/m^3, (or 626 ng/m^3) and exposure parameters used by PANNA on page 33 of their report:
>
> Inhalation Dose = 0.626 μg/m^3 * 0.1875 m^3/hr * 0.001 mg/ug * 2 hours / 7.6 kg bw = 0.0000308 mg/kg/day.
>
> **MOE = 6298** = 0.194 mg/kg/day/0.0000308 mg/kg/day for a one-year-old child playing for 2 hours on a playground having 0.626 μg/m^3 diazinon in the air.

For endosulfan, EPA considers a MOE of greater than 1000 acceptable for children. This MOE is based on a 10X uncertainty factor to account for differences between animals and humans, a 10X uncertainty factor to account for differences between different people, and a 10X FQPA uncertainty factor to account for possible increased sensitivity in children.

If this calculation were to be applied using a more realistic exposure scenario involving a child older than one year, the resulting risk would be even less.

DIAZINON HEALTH-BASED COMPARISON VALUES

The maximum diazinon value of **897 ng/m^3** reported by PANNA is less than acute and chronic comparison values for diazinon that are used by federal agencies in their risk assessments. One authoritative alternate health-based comparison value found for diazinon is the ATSDR (U.S. Public Health Service) intermediate-duration inhalation Minimal Risk Level (MRL) of **10,000 ng/m^3**. The intermediate duration inhalation MRL applies to exposure durations of greater than two weeks and up to one year.

ATSDR derived the MRL of 10,000 ng/m^3 based on a NOAEL of 1.57 mg/m^3 (duration-adjusted to 0.28 mg/m^3) for RBC acetylcholinesterase inhibition observed in a 21-day study in hybrid rats (Hartmann, 1990). The NOAEL was converted to a **Human Equivalent Concentration No Observable Adverse Effect Level of 0.44 mg/m^3 (440,000 ng/m^3),** which was then divided by an uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability), and then rounded down to derive the intermediate MRL. The ATSDR provides a discussion of their rationale for the specific diazinon MRL value in the Draft Toxicological Profile for Diazinon (ATSDR, 2006; ITER, 2007).

The USEPA Regions 3, 6, and 9 use a chronic screening value of **3,300 ng/m^3** for diazinon in their risk assessments (USEPA, 2007b; USEPA, 2007c; USEPA, 2004c). Use of this value for acute or subchronic exposure scenarios should be highly protective, since this is considered to be an acceptable level even with continuous, long-term exposure.

In its 2000 USEPA Human Health Risk Assessment for diazinon, the USEPA selected a rat inhalation study in their inhalation risk assessment for diazinon in which rats were exposed whole body 6 hours per day for 21 days. A **LOAEL** of 0.1 μg/L (or **100,000 ng/m^3**), corresponding to a dose of 0.026 mg/kg/day, was determined to be the lowest level causing reversible inhibition of cholinesterase activity in serum and red blood cells (USEPA, 2004d). The USEPA applied an uncertainty factor of 300 (10X for intraspecies variation, 10X for interspecies variation, and 3X for extrapolating from a LOAEL to a NOAEL since a NOAEL was not determined in this 21-day rat inhalation study).

In calculating inhalation risks to children playing on lawns treated with diazinon, the USEPA indicated on page 161 of the 2000 Human Health Risk Assessment for diazinon that one of the most important factors that contribute to the possible over-estimation of risk is “Use of a 21 day inhalation toxicity endpoint based on whole body exposure in rats to assess a 2 hour exposure scenario.” It is significant that the key study used by the Agency to assess adverse effects from inhalation exposure actually measured effects from combined inhalation, dermal, and also likely some amount of oral exposure. Rats tested by whole-body inhalation exposure may have substantial ingestion of the test material due to grooming the hair following exposure. Moreover, absorption of diazinon through human skin is reportedly much less than that in rats (WHO, 1998; Wester, 1993). Given the potential for organophosphates to absorb through the skin of rats, coupled with the fact that rats have a greater skin surface area to body weight ratio than humans, it is likely that the risk to humans would be overestimated when using the study selected by the USEPA.

Calculating Acceptable Exposure Level for Diazinon Using the USEPA Margin of Exposure Approach

The Agency calculated inhalation risks to children breathing diazinon using the “Margin of Exposure” (MOE) concept in the equation on page 170 of the “Human Health Risk Assessment” document for diazinon (USEPA, 2000a).

If this USEPA equation is used to calculate the inhalation risk to a one-year-old child playing at the school, assuming that the maximum concentration of diazinon reported by PANNA is present in the air for a realistic 2-hour duration, there is no unacceptable risk:

> MOE = LOAEL/inhalation dose.
>
> LOAEL = 0.026 mg/kg/day, based on a 21-day rat inhalation study used in the USEPA risk assessment for diazinon.
>
> Inhalation Dose (mg/kg/day) = {air concentration (μg/m^3)* inhalation rate (m^3/hr)*0.001 mg/ug*2 hours}/ body weight (kg).
>
> Inserting the highest detected diazinon value of 0.897 μg/m^3, and exposure parameters used by PANNA on page 33 of their report:
>
> Inhalation Dose = 0.897 μg/m3 * 0.1875 m^3/hr * 0.001 mg/ug * 2 hours / 7.6 kg bw = 0.0000442 mg/kg/day.
>
> **MOE = 588** = 0.026 mg/kg/day / 0.0000442 mg/kg/day for a one-year-old child playing for 2 hours on a playground having 0.897 μg/m^3 diazinon in the air.

For diazinon, EPA considers a MOE greater than 300 to be an acceptable risk. This MOE is based on a 10x uncertainty factor to account for differences between animals and humans, a 10x uncertainty factor to account for differences between different people, and a 3x uncertainty factor to account for using a LOAEL instead of a NOAEL in the calculation. (The USEPA concluded that a 10x FQPA uncertainty factor was not warranted for diazinon). If this calculation were to be applied using a more realistic exposure scenario involving a child older than one year, the resulting risk would be further reduced.

The USEPA has evaluated studies reporting on the exposure of farm children diazinon and other pesticides following drift and volatilization, and the Agency concluded that “There is no reason to expect any meaningful exposure due to volatilization…” and that the data “do not demonstrate that children in agricultural areas as a group receive more pesticide exposure than in non-agricultural areas” (USEPA, 2005). The USEPA conclusion that airborne diazinon does not typically contribute to any significant risk is consistent with conclusions reached by other authoritative bodies that exposure to airborne diazinon at much greater levels than that reported in Hastings does not present unacceptable risk to children (APVMA, 2006).

TRIFLURALIN HEALTH-BASED COMPARISON VALUES

The maximum trifluralin value of **376 ng/m^3** reported by PANNA is less than acute and chronic comparison values for trifluralin that are used by federal agencies in their risk assessments. The USEPA Air, Pesticides, and Toxics Management Division recommends a chronic inhalation screening value of **450 ng/m^3** for trifluralin (USEPA, 2006h). The USEPA has also recommended acute screening values of **25,000 ng/m^3** and **75,000 ng/m^3** which correspond to TEEL0 and TEEL1 values for trifluralin (USEPA, 2006h).

B. Other Potential Sources of Exposure to these Compounds

Page 6 of the PANNA report states, "Inhalation may not be the sole exposure source, and total exposures from all routes (air, skin, diet) may be higher." It is likely that in addition to exposure to the pesticides in air there are also other sources of exposure to the same compounds through food, water, and other pathways.

Aggregate exposure is appropriately assessed by the USEPA in its risk assessment process. However, the USEPA has determined that expected levels of these pesticides in food are negligible and are acceptable levels for both infants and adults, even when combined with exposure from all other expected sources and other permitted uses. Moreover, testing by SJCSB demonstrated that levels in soil were well below the Florida Soil Cleanup Target Levels for residential areas. It is unlikely that children at the school would incur any significant additional exposure to the pesticides after incidentally ingesting the soil or having the soil contact the skin, or from residue of these pesticides in their food or water, although this may vary depending on a given individual's dietary sources, residential location and various other factors.

C. Additive or Synergistic Effects of Concurrent Exposure to These Compounds

PANNA raised the possibility that synergistic toxic effects might result from exposure to the mixture of the three pesticides. Page 7 of the PANNA report states, "No 'acceptable' levels have been established for exposures to multiple pesticides simultaneously. It is possible that additive or synergistic effects may increase the toxicity of one pesticide in the presence of others."

Information on any potential interaction of chemicals in a mixture is evaluated as part of the human health risk assessment for any newly registered pesticides or pesticides undergoing reregistration (USEPA, 2004e; ATSDR, 2004). A number of governmental guidance documents, literature reviews, and other scientific papers have been produced on the topic of synergism. While there are possible exceptions, studies have generally shown that humans exposed to chemical mixtures are not at risk of having significant adverse health effects, provided that all of the individual chemicals in the mixture are at non-toxic doses (ATSDR, 2004; USEPA, 2004e; USEPA, 2003b; USEPA, 2000c; USEPA, 1999b; USEPA, 1988; USEPA, 1986; EMI SIG, 2007b; NAS, 1994; NAS, 1988; WHO, 1990; Ito et al., 1996; Carpy et al., 2000; Jensen et al., 2003; Carpenter et al., 2002).

It has long been known that for a subset of selected co-administered organophosphates given in sufficiently high doses, there is a demonstrated synergistic (*i.e.*, greater than additive) effect (Frawley et al., 1957). However, synergism is the exception rather than the rule. Most often there is approximately an additive toxic effect when there is exposure to different chemicals at the same time. In some cases, the combined effect may be less than additive (*i.e.*, one chemical negates the toxic effects of another, an antagonistic effect). A review of the EPA assessments for the pesticide active ingredients discussed in this report indicate that these compounds are not known to share a common mechanism of action with each other. The three chemicals at issue in this report belong to different chemical classes: diazinon is an organic phosphorus (organophosphate) insecticide; endosulfan is an organochlorine insecticide; trifluralin is a dinitroaniline herbicide. Diazinon affects the nervous system through cholinesterase inhibition. Endosulfan is also a weak cholinesterase inhibitor, but only at the highest doses given in animal studies (USEPA, 2002a; USEPA, 2002b). While diazinon and endosulfan both target the nervous system, they generally affect the nervous system through different mechanisms, and there are no scientific grounds to conclude that their combined effect on the nervous system would be more than additive. Whereas diazinon exposure at high levels can be expected to cause cholinesterase inhibition, endosulfan may only weakly inhibit cholinesterase, if at all, and its contribution to the overall inhibition would be negligible.

D. Protection of Children

Much has been written on the potential for children to be more susceptible than adults to toxins (USEPA, 2007d; USEPA, 2006i; USEPA, 2006j; USEPA, 2006k; USEPA, 2002; USEPA, 1995; ATSDR, 2006; Moya, 2004; Williams et al., 2006; Scheuplein et al., 2002). Children are thought to be more susceptible to toxins than adults for several reasons:

1. Children have a higher inhalation rate relative to their body weight than adults
2. Children consume more of certain foods and water relative to their body weight than adults
3. Young children play close to the ground and come into contact with contaminated soil outdoors and with contaminated dust on surfaces and carpets indoors, and concentrations of pesticides in the vapor phase may be greater close to the grounds than at greater heights in the adult breathing zone
4. Toddlers often engage in mouthing behavior
5. Nursing infants may be exposed to some toxins that are excreted in their mother’s breast milk
6. Infants sometimes metabolize chemicals differently than adults
7. Children have a larger skin surface in proportion to their body volume, and their skin may also absorb some substances more easily than adults
8. Infants’ immune systems are not as strong as that of healthy adults

The USEPA concluded in their recent risk assessment that the 10X FQPA uncertainty factor would be required in the risk calculations for endosulfan, an organochlorine pesticide (2002), although the Agency determined that a 10X FQPA uncertainty factor was not warranted for the organophosphate compound diazinon (USEPA, 2004d).

The 1993 National Research Council report, “Pesticides in the Diets of Infants and Children” concluded that changes were needed in the regulation of pesticides to reduce exposure of children to certain pesticides in food (NRC, 1993; NRC, 2003). Following this study, the Food Quality Protection Act of 1996 was implemented. Under the FQPA, the USEPA is required to apply an additional uncertainty factor of 10 to protect children where there is evidence that children may be at greater risk of adverse effects from pesticides than adults or if there is not sufficient evidence to the contrary. This is in addition to the uncertainty factor of 10 to account for difference between species and another factor of ten to account for the difference between individuals. Therefore, the USEPA in such cases uses an aggregate uncertainty factor of 1000, which means that an acceptable level of exposure for a child would be no greater than a thousand times less than a level causing minimal or no effect in the most sensitive animal species tested. Some researchers have concluded that the 10-fold uncertainty factor for human variability, without the additional FQPA factor, is almost always sufficient to protect virtually all of the population, including children (Dourson et al., 2002). Even in cases where specific metabolizing enzymes may be significantly less efficient in some children or adults (*e.g.*, by more than a factor of ten), other metabolizing enzymes present in humans generally compensate at least to some extent (Mutch et al., 2007; Lee et al., 2007; Gentry et al., 2002; Poet et al., 2003; O'Leary et al., 2005; Wheelock et al., 2005; Furlong et al., 2007; Furlong et al., 2006; Costa et al., 2005; NRC, 2003; Cole et al., 2003; Mackness et al., 2003 et al., 2002; Davies et al., 1996; Haley et al., 1999). The total uncertainty factor is likely to be highly protective of nearly all individuals, including children.

The USEPA has re-evaluated organophosphate pesticides individually and as a group following issuance of the 1993 NRC report and recent studies indicating that some organophosphate compounds may persist in indoor environments (*e.g.*, Lee et al., 2002). In recognizing the potential for diazinon and some other organophosphates to accumulate and reach potentially unsafe levels inside of the home, the Agency cancelled the indoor use of diazinon products (USEPA, 2004d). The USEPA concluded in its evaluations that with sufficiently high exposure levels, children might be more susceptible to some organophosphates, but not others, such as diazinon. The USEPA conclusion that diazinon does not pose more significant toxicological risks to children compared to adults is supported by several recent reports (Kousba et al., 2007; NRC, 2003; OEHHA, 2001).

IV. Uncertainties

1. **The studies did not directly measure the children's exposure to pesticides.** Although both studies provide rough estimates of exposure through air monitoring of pesticides, with the SJCSB study located at the school, neither of the studies directly measured children's exposure to pesticides. Children spend the majority of their time away from the school property. When they are at school, they are likely to be indoors for most of that time, and different children enter and leave different areas of the school at different times. Since personal air monitoring samples were not used and biological monitoring for pesticide exposure was not conducted, the actual amount of pesticides to which the children are exposed was not measured.

2. **How well do the air samples collected from a residence some distance from the school represent the air at the school?** PANNA did not measure pesticide levels on the school grounds, but rather at a residence located some distance from the school, albeit at a similar distance away from the field as the school. This is an approximate surrogate for that which existed at the school at the time the samples were collected. Of particular importance may be the large forested area between a large portion of the fields and the

school, which may potentially serve as a barrier to pesticide transport and trap pesticide laden air in that area, but might also serve as a sink in which pesticides are slowly released into the air. While SJCSB measured outdoor air at the school, this also likely overestimates the actual exposure to the children. School children spend the majority of their time indoors when they are at school, so indoor concentrations account for the bulk of their inhalation exposure (USEPA, 2007d).

3. **How well did the periods in which samples were collected represent other times during the year?** The PANNA samples and the SJCSB samples were not collected at the same time, and therefore the results cannot be directly compared. Moreover, the times at which samples were collected reflect pesticide levels in the air only for the specific times in which the samples were taken. The flux rates and dispersion of these pesticides in air, and the resulting levels in air to a large extent would depend on the days and times in which the pesticides were applied, in addition to other factors such as temperature, humidity, wind speed and direction. Pesticides are applied only during the growing season, and the labels for each of these pesticide formulations limit the amount and the number of times in which the products may be used, and the levels of pesticides detected on application days or shortly thereafter would likely be greater than at other times. Also, there is an apparent discrepancy in pesticide application dates listed in the PANNA report compared to the application records obtained from the grower by FDACS.

4. **There is uncertainty over the physical form in which the pesticides were detected in air.** Pesticides measured in the air may be bound to dust particulates, they may be in large aerosol droplets or in a fine mist, or they may be in the air in the gas phase following volatilization. The form in which a compound is present in the air is an important factor affecting the extent to which it remains airborne. The portion that is volatized to the gas phase remains in air for the longest amount of time, and thus presents the greatest potential for long-term inhalation exposure. Moreover, if a compound is bound to large, coarse particulates, it is not readily absorbed into the lungs when inhaled, but rather, it is deposited in the upper respiratory tract where it is less systemically available. Conversely, the portion that is bound to fine particulate matter or is in the gas phase is readily taken up through the lungs (Wilbur, 1998). The analytical methods used in both studies, although appropriate, may overestimate risks, since neither of the study methods distinguished between volatile gas phase pesticide and particulate-bound pesticide. Although this is a health-protective practice that assumes 100% of the amount of pesticides in air is bioavailable in the lungs, in fact this may overestimate the true exposure. The Executive Summary of the PANNA report states, “The fact that pesticides were detected on most days indicates that volatilization of the pesticides is the primary source of the drift, although application-related drift may have contributed on the day(s) application took place.” FDACS has no evidence that “drift” (which is defined as aerosol or particulate matter moving off of the agricultural field as a direct result of the way in which the product was applied) occurred in the fields near the school during times in which samples were collected for either of the studies. Based on monitoring studies and on the physico-chemical properties of these semi-volatile pesticides, it is likely that the three compounds volatize at least in part to the gas phase, although significant proportions of these compounds are also likely to be bound to particulate matter. The

PANNA results show that the concentrations measured in air (although relatively low at all times) varied considerably. Peak levels were measured during pesticide applications or shortly thereafter, and on some days one or more of the three pesticides were not detected. A quickly decreasing amount of volatizing pesticides following application (over hours to days) is consistent with what is reported in the literature for these compounds. Given that diazinon quickly degrades in the environment to diazoxon, and that PANNA did not detect diazoxon, it is possible that the source of the diazinon was from a fairly recent application.

5. **There is some uncertainty regarding the variation of wind direction and speed.** The direction and speed of the wind are not constant over time. Weather records for the periods in which air sampling occurred in Hastings indicate that the wind direction and speed changed several times. Although it would be inappropriate and unrealistic to sum pesticide concentrations in air from all sides of the field, since a pesticide plume in the air would not be expected to travel in a single direction for 24 hours and would dissipate to some extent over time as it moved, the exposure duration may nevertheless be greater when the air is moving slowly in a single direction from the field toward the school. However, the assessment assumes that the children are exposed continuously to the highest concentration detected in air, when in reality the wind direction could be away from the school for much of that time.

6. **There is some uncertainty over the reliability of the 24-hour samples as a result of the reported variability in the flow rates in the sample apparatus.** Substantial variability was reported in the flow rates for some of the PANNA samples (PANNA, 2007), and depending on whether the flow increased or decreased from that expected, the actual concentration in air would be proportionally greater or less than that reported.

7. **There is uncertainty over the extent to which 24-hour samples represent pesticide exposure at the school.** The children are not likely to be at the school more than 8 hours per day, and are not likely to be outdoors on the school grounds for much more than an hour or two per day. It has not been shown whether the pesticide concentrations in the air would be greater during the day or the night. The 24-hour sample value is a daily average value that might be suitable for ambient air monitoring under continuous exposure scenarios, but is much less relevant to an 8-hour school day setting. Given that 24-hour samples were reported, it may be appropriate to adjust the calculations for an appropriate health comparison value to reflect that the school children are not outdoors near the agricultural fields for 24 hours per day and 365 days per year.

8. **There is some uncertainty over the children's inhalation rates.** Children at play may inhale air at greater rates than normal for at least part of the play time, which could potentially increase their risk compared to children at rest. The child inhalation rates used by PANNA in their report, however, reflect breathing rates recommended in the USEPA's Exposure Factors Handbook. A one-year-old infant would not be capable of engaging in activities typical of older children, such as running, and therefore it is not clear that the potential for increased breathing rates would occur. However, even if the average inhalation rates are moderately increased to account for increased activity, there

should still be no unacceptable risks to the children at the school given the short time they are at play and the low levels of exposure compared to health-based guideline comparison levels in air that have been established by the USEPA and the ATSDR.

9. **Given the few sample results in both studies, there is uncertainty over how the sample results should be weighted.** Both the PANNA and the SJCSB studies were able to collect only a limited number of samples, precluding a more thorough analysis of the site. The pesticide levels reported by PANNA for a given pesticide varied considerably over time and in several instances were not detected. The most conservative approach was used by PANNA in which the maximum detected values were compared to the PANNA RELs. A more realistic approach would be to use a more representative central tendency value (*e.g.*, mean or median) or even an upper bound (*e.g.*, upper 95% confidence interval) value that includes the entire data set. Ideally, once a sufficient number of data points are available, an air model can be derived to present a more refined exposure analysis. Neither the PANNA nor the SJCSB reports provided an air modeling analysis.

10. **There is some uncertainty over which health-based comparison values are most appropriate for the scenario at the school.** Different authoritative bodies may interpret key studies differently or may in some cases use different studies altogether, and may apply different uncertainty factors in deriving acceptable levels of exposure. Different comparison values may be based on different sample populations and exposure durations. However, common to all of these assessments is the practice of starting with either a level that causes no adverse effect or the lowest level causing a minimal effect in a susceptible animal, and then lowering that level by many times before it is considered to be an acceptable human exposure level. The USEPA and ATSDR health-based comparison values noted in this report are all expected to be sufficiently protective, given that they represent acceptable levels of continuous exposure for adults and children for long durations ranging from a year up to a lifetime.

11. **Peak levels could potentially be greater than that reported in the PANNA 24-hour samples.** While it is possible that over the course of 24-hour sampling, the levels may have briefly exceeded the average 24-hour value, if that was the case it was also at times lower than the average reported value. However, given that even the maximum 24-hour values reported by PANNA and also the levels not detected in the air at the school by SJCSB over shorter sampling times of up to eight hours (which are more representative of when the children would be at school) are both well below authoritative acute and chronic comparison values, this point of uncertainty is not of great significance.

12. **The USEPA endosulfan inhalation reference concentration of 21,000 ng/m^3 is derived from effects in an animal study following *oral* exposure rather than an *inhalation* exposure.** It is preferable to use an animal study in which there is an inhalation exposure when that is the most applicable route of administration in the case at hand. Nevertheless, extrapolating health effects from one exposure route to another (*e.g.*, from oral to inhalation) is a common and accepted practice and is appropriate if there is some available information regarding the manner in which the compound is metabolized

in the respiratory tract prior to its entry into the bloodstream (USEPA, 2004a). In addition, when this is done, an additional uncertainty factor may be added in the risk calculation to account for the extrapolation, and it is conservatively assumed that 100% of a compound is absorbed through inhalation as in the case of ingestion. Furthermore, the final derived comparison value of 21,000 ng/m^3 is more than an order of magnitude greater than the maximum reported endosulfan value of 626 ng/m^3, and it is unlikely that the amount of uncertainty from this extrapolation could change the conclusion that endosulfan was not at a level of concern in Hastings. This is further supported by the calculation of a MOE for a one-year-old child exposed to the maximum concentration of endosulfan for two hours using the 21-day rat inhalation study NOAEL, in which case there is still no elevated risk.

V. Conclusions and Recommendations

In this report, FDACS has compared and contrasted the pertinent details of the PANNA and SJCSB air monitoring studies with regard to their respective methods of sample collection, analysis and data interpretation. While preparing this report, FDACS consulted various government agencies and other authoritative bodies, and independently reviewed the available scientific literature on these pesticides in order to characterize risks and to identify areas of uncertainty in the evaluation.

Based on the analytical data presented by PANNA and the SJCSB, and given the limitations of those data, FDACS concludes that these studies do not demonstrate that airborne pesticides pose an imminent or chronic health threat to children or adults present at this school. This conclusion is based on the finding that in both studies, the highest concentration of these pesticides detected in the air were all well below guidance concentrations established by various federal authoritative bodies. Calculations of risks using USEPA formulae also indicate that there are no unacceptable risks. In addition, the trace levels of pesticides detected in the soil at the school were well below Florida residential Soil Cleanup Target Levels established by the Florida Department of Environmental Protection.

FDACS disagrees with PANNA’s conclusion that there is a significant health risk associated with the levels of pesticides reported in the air in Hastings, and we do not entirely concur with the methods used in their risk analysis. While we agree with the overall conclusion reached by the SJCSB that the pesticide levels in the air pose no significant health risks, we arrived at this determination using different health-based comparison values than the SJCSB, rather than using occupational threshold values. The data contained in both of the reports are of value to FDACS with respect to pesticide regulation, since they shed light on a unique pathway for transport of semi-volatile pesticides from an area of application that is not typically evaluated by FDACS or the USEPA during the registration process. Indeed, as indicated by the USEPA’s recent interest in bystander exposure from highly volatile soil fumigants, future air quality issues are likely to receive greater attention at the federal and state level.

Notwithstanding our conclusion that the levels of pesticides detected at the Hastings school indicate that health risks there are quite low, FDACS nevertheless recommends adopting the following precautionary steps to further minimize the potential for future agricultural activity to impact schools and similarly sensitive sites:

1. FDACS should work with urban/agricultural pesticide specialists at the University of Florida Institute of Food and Agricultural Sciences to pursue grant funds for an educational/outreach program for pesticide applicators who operate near schools. This "good neighbor" program would help growers identify methods to reduce the potential for pesticides drifting into school grounds and would assist in improving relations between growers and their neighbors. The program would seek to enhance communications regarding pesticide safety and modern agricultural practices, and would encourage mutually beneficial coordination of farm and school activities.
2. As resources allow, the Department will seek to expand its efforts to coordinate the assessment of potential pesticide air quality impacts with the USEPA, the Florida Department of Health, and the Florida Department of Environmental Protection.
3. As resources allow, the Department will continue to seek funding for monitoring, modeling, and chemical analytical tools needed to refine our ability to characterize airborne pesticide exposures and their potential impact to human health.
4. If unacceptable risks are identified, the Department will pursue measures to mitigate those risks, through appropriate regulatory approaches, and through sustained implementation of pesticide registrant stewardship programs and applicator best management practices.

VI. References

APVMA (Australian Pesticides & Veterinary Medicines Authority). 2006. The reconsideration of approvals of the active constituent diazinon, registrations of products containing diazinon and approval of their associated labels. Part 2. Preliminary Review Findings. Volume 2 of 2. Technical Reports. June 2006. Available on the internet at http://www.apvma.gov.au/chemrev/diazinon_PRF_vol2.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2006. Draft Toxicological Profile for Diazinon. September, 2006. Department of Health and Human Services, U.S. Public Health Service. Available on the internet at http://www.atsdr.cdc.gov/toxprofiles/tp86.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2005. ATSDR Public Health Assessment Guidance Manual. Appendix F. Derivation of Comparison Values. Available on the internet at http://www.atsdr.cdc.gov/HAC/phamanual/appf.html

ATSDR (Agency for Toxic Substances and Disease Registry). 2004. Guidance Manual for the Assessment of Joint Action of Chemical Mixtures. U.S. Department of Health and Human Services. Available on the internet at http://www.atsdr.cdc.gov/interactionprofiles/ipga.html

ATSDR (Agency for Toxic Substances and Disease Registry). 2003. Health Consultation. Analysis of Human Exposure Pathways for Pesticide Use in Churchill County. Fallon Leukemia Project. Fallon, Churchill County, Nevada. July 18, 2003. Pages 14-18, 50. Available on the internet at http://www.atsdr.cdc.gov/sites/fallon/fallonleukemia062503-ne-pesticide-pt1.pdf

ATSDR (Agency for Toxic Substances and Disease Registry). 2001. ToxFAQs for Endosulfan. Department of Health and Human Services, U.S. Public Health Service. Available on the internet at http://www.atsdr.cdc.gov/tfacts41.html

ATSDR (Agency for Toxic Substances and Disease Registry). 2000. Toxicological Profile for Endosulfan. Department of Health and Human Services, U.S. Public Health Service. Available on the internet at http://www.atsdr.cdc.gov/toxprofiles/tp41.html

Bedos, C. et al. 2006. Measurement of trifluralin volatilization in the field: Relation to soil residue and effect of soil incorporation. Environ. Pollut. 144(3):958-966. Abstract.

Belzer, W. et al. 1998. Atmospheric concentrations of agricultural chemicals in the lower Fraser Valley. Aquatic & Atmospheric Sciences Division, Environment Canada. Vancouver, B.C. January 1998. Available on the internet at http://www.rem.sfu.ca/FRAP/9731.pdf

Bidleman et al., 1995. As cited by NAS, 1999.

Bouvier, G. et al. 2006. Pesticide exposure of non-occupationally exposed subjects compared to some occupational exposure: a French pilot study. Sci. Total Environ. 366(1):74-91. Abstract.

Bradman, A. and R.M. Whyatt. 2005. Characterizing exposures to nonpersistent pesticides during pregnancy and early childhood in the National Children's Study: A review of monitoring and measurement methodologies. Environ. Health Perspect. 113(8):1092-1099. Available on the internet at http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1280354&blobtype=pdf

Buehler, S.S. et al. 2004. Causes of variability in pesticide and PCB concentrations in air near the Great Lakes. Environ. Sci. Technol. 38(2):414-422. Abstract.

CalEPA (California Environmental Protection Agency). 2007. Acute RELs, Chronic RELs. Office of Environmental Health Hazard Assessment. Available on the internet at http://www.oehha.ca.gov/air/acute_rels/response4_4.html

Carey, A. E., and F.W. Kutz. 1985. Trends in ambient concentrations of agrochemicals in humans and the environment of the United States. Environ. Monitor. Assess. 5:155-163. Cited by ATSDR, 2006.

Carpenter, D.O. et al. 2002. Understanding the human health effects of chemical mixtures. Environ. Health Perspect. 110(Suppl-1):25-42. Available on the internet at http://ehp.niehs.nih.gov/members/2002/suppl-1/25-42carpenter/EHP110s1p25PDF.PDF

Carpy, S.A. et al. 2000. Health risk of low-dose pesticides mixtures: a review of the 1985-1998 literature on combination toxicology and health risk assessment. J. Toxicol. Environ. Health B. Crit. Rev. 3(1):1-25. Abstract.

CDPR (California Department of Pesticide Regulation). 1995. Monterey County Residential Air Monitoring. Available on the internet at http://www.cdpr.ca.gov/docs/empm/pubs/ehapreps/eh8507.pdf

ChemID plus. Toxicity database. 2007. U.S. National Libarary of Medicine. Available on the internet at http://chem.sis.nlm.nih.gov/chemidplus/

Clayton, A. et al. 2003. Distributions, associations, and partial aggregate exposure of pesticides and polynuclear aromatic hydrocarbons in the Minnesota Children's Pesticide Exposure Study (MNCPES). J. Expo. Anal. Environ. Epidemiol. 13(2):100-111. Abstract.

Cole, T.B. et al. 2003. Expression of human paraoxonase (PON1) during development. Pharmacogenetics. 13(6):357-364. Abstract.

Costa, L.C. et al. 2005. Modulation of paraoxonase (PON1) activity. Biochem. Pharmacol. 69:541-550. Available on the internet at http://www.firat.edu.tr/perweb/personel/yayinlar/fua_870/870_21956.pdf

Currie, K.L. et al. 1990. Concentrations of diazinon, chlorpyrifos, and bendiocarb after application in offices. Am. Ind. Hyg. Assoc. J. 51(1):23-27. Abstract.

Davies, H.G. et al. 1996. The effect of the human serum paraoxonase polymorphism is reversed with diazoxon, soman and sarin. Nat. Genet. 14(3):334-336. Abstract.

DeRosa, C.T. et al. 1998. Public health implications of environmental exposures. Environ. Health Perspect. 106 Suppl. 1: 369-378. Available on the internet at http://www.atsdr.cdc.gov/mrls/articles/public_health_implications_of_environmental_exposures.pdf

Dourson, M. and R. Scheuplein. 2002. Differential sensitivity of children and adults to chemical toxicity. II. Risk and regulation. Reg. Tox. Pharmacol. 35:448-467. Available on the internet at http://www.tera.org/pubs/Dourson%202002.pdf

EMI SIG (Emergency Management Issues Special Interest Group). 2007a. Protective Action Criteria for Chemicals- TEEL Values including AEGLs and EWRPGs. Subcommittee on Consequence Assessment and Protective Actions. Available on the internet at http://orise.orau.gov/emi/scapa/teels.htm

EMI SIG (Emergency Management Issues Special Interest Group). 2007b. The Chemical Mixture Methodology Using Health Code Numbers. Available on the internet at http://orise.orau.gov/emi/scapa/hcn.htm

EXTOXNET. 2007. Pesticide Information Profiles. Extension Toxicology Network. EXTOXNET is a cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Conrell University, and the University of Idaho. Available on the internet at http://extoxnet.orst.edu/pips/ghindex.html

EXTOXNET. 1993. Cholinesterase Inhibition. Toxicology Information Briefs. Extension Toxicology Network. EXTOXNET is a cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Conrell University, and the University of Idaho. Available on the internet at http://extoxnet.orst.edu/tibs/cholines.htm

Faustman, E.M. and G.S. Omenn. 2003. Chapter 4 Risk Assessment. Pages 46-56. In Casarett & Doll's Essentials of Toxicology. eds. Klaassen and Watkins III. The McGraw-Hill Companies, Inc. U.S.

Frawley, J.P. et al. 1957. Marked potentiation of mammalian toxicity from simultaneous administration of two anticholinesterase compounds. J. Pharmacol. & Exptl. Therapeutics. 212:96-106.

Furlong, C.E. 2007. Considerations for Exposure to Diazinon and Chlorpyrifos. Power point presentation available on the internet at http://www.gs.washington.edu/outreach/FurlongOPExposures.ppt

Furlong, C.E. et al. 2006. PON1 status of farmworker mothers and children as a predictor of organophosphate sensitivity. Pharmacogenetics and Genomics. 16:183-190. Available on the internet at http://ehs.sph.berkeley.edu/Holland/Genomics/statuspaper.pdf

Gentry, P.R. et al. 2002. An approach for the quantitative consideration of genetic polymorphism data in chemical risk assessment: examples with warfarin and parathion. Toxicol. Sci. 70(1):120-139. Available on the internet at http://www.tera.org/pubs/polygentry2002.pdf

Glotfelty, D.E. et al. 1990a. Distribution of several organophosphorus insecticides and their oxygen analogues in a foggy atmosphere. Environ. Sci. Technol. 24:353-357. Cited by ATSDR, 2006.

Glotfelty, D.E. et al. 1990b. Studies of the distribution, drift, and volatilization of diazinon resulting from spray application to a dormant peach orchard. Chemosphere 21:1303-1314. Cited by ATSDR, 2006.

Goel, A. et al. 2005. Environmental Management and Byproduct Utilization Laboratory. Atmospheric Processes of Agricultural Pollutants that Affect Air and Water Quality. June 28, 2005. Available on the internet at

Gordon, S.M. et al. 1999. Residential environmental measurements in the national human exposure assessment survey (NHEXAS) pilot study in Arizona: preliminary results for pesticides and VOCs. J. Expo. Anal. Environ. Epidemiol. 9(5):456-470. Cited by ATSDR, 2006.

Gouin, T. et al. 2005. Passive and active air samplers as complementary methods for investigating persistent organic pollutants in the Great Lakes Basin. Environ. Sci. Technol. 39(3):9115-9122. Abstract.

Grover, R. et al. 1997. Environmetal fate of trifluralin. Rev. Environ. Contam. Toxicol. 153:1-64. Abstract.

Haley, R.W. et al. 1999. Association of low PON1 type Q (type A) arylesterase activity with neurologic symptom complexes in Gulf War veterans. Toxicol. Appl. Pharmacol. 157(3):227-233. Abstract.

Hapeman, C. et al. 2006. Reducing the Risks of Pesticide Exposure Via Atmospheric Transport. Atmospheric Processes of Agricultural Pollutants that Affect Air and Water Quality. Meeting Abstract. June 4, 2006. United States Department of Agriculture Agricultural Research Service. Available on the internet at http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=198041&pf=1

Hapeman, C. et al. 2005. Agrochemical Fate in South Florida Ecosystems. Atmospheric Processes of Agricultural Pollutants that Affect Air and Water Quality. Meeting Abstract. February 13, 2005. United States Department of Agriculture Agricultural Research Service. Available on the internet at http://www.ars.usda.gov/research/publications/

Harner, T. et al. 2006. Global pilot study for persistent organic pollutants (POPs) using PUF disk passive air samplers. Environ. Pollut. 144(2):445-452. Abstract.

Harner, T. et al. 2005. Hexachlorocyclohexanes and endosulfans in urban, rural, and high altitude air samples in the Fraser Valley, British Columbia: evidence for trans-Pacific transport. Environ. Sci. Technol. 39(3):724-731. Abstract.

Harnly, M. et al. 2005. Correlating agricultural use of organophosphates with outdoor air concentrations: A particular concern for children. Environ. Health Perspect. 113(9):1184-1189.Available on the internet at http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1280399&blobtype=pdf

Hartmann, H.R. 1990. G 24`480 tech.: 21-day repeated exposure inhalation toxicity in the rat - Nose-only exposure (Project No. 891205). Basel, Switzerland, Ciba-Geigy Ltd (Unpublished report). Cited by WHO, 1998.

Hatzilazarou, S.P. et al. 2004. Dissipation of three organochlorine and four pyrethroid pesticides sprayed in a greenhouse environment during hydroponic cultivation of gerbera. Pest. Manag. Sci. 60(12):1197-1204. Abstract.

Hayes, A.L. et al. 1980. Assessment of occupational exposure to organophosphates in pest control operators. Am. J. Hyg. Assoc. J. 41(8):568-575. Abstract.

Hayes, W.J. Jr. and E.R. Laws, Jr., eds. 1991. Handbook of Pesticide Toxicology. Vols. 1-3. Academic Press, Inc. San Diego, CA.

HSDB (Hazardous Substance Databank). 2007. U.S. National Institutes of Health. Online database available on the internet at http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

ICPS (International Centre for Pesticides and Health Risk Prevention). 2002. Organophosphorus Insecticides: Toxicological Issues. Available on the internet at http://www.icps.it/english/bollettino/psn98/980201.htm

INCHEM (International Programme on Chemical Safety). 1994. Evaluations. Part II. Toxicology. Sponsored jointly by FAO and WHO. Available on the internet at http://www.inchem.org/documents/jmpr/jmpmono/v89pr01.htm.

ITER (International Toxicity Estimates for Risk Database). 2007. Diazinon. Available on the internet at http://iter.ctcnet.net/publicurl/pub_view_l2_non.cfm?crn=333%2D41%2D5&type=NCI

Ito, N. et al. 1996. Effects of pesticide mixtures at the acceptable daily intake levels on rat carcinogenesis. Food Chem. Toxicol. 34(11-12):1091-1096. Abstract.

Jensen, A.I. et al. 2003. Cumulative risk assessment of the intake of organophosphorus and carbamate pesticides in the Danish diet. Food Addit. Contam. 20(8):776-785. Abstract.

Kannan, K. et al. 2003. Trace organic contaminants, including toxaphene and trifluralin, in cotton field soils from Georgia and South Carolina, USA. Arch. Environ. Contam. Toxicol.

45:30-36. Available on the internet at http://www.springerlink.com/content/2h07rqp316mwevq3/fulltext.pdf

Kiraly, J. et al. 1979. Chromosome studies in workers producing organophosphate insecticdes. Cited by HSDB, 2007.

Kousba, A. et al. 2007. Age-related brain cholinesterase inhibition kinetics following in vitro incubation with chlorpyrifos-oxon and diazinon-oxon. Toxicol. Sci. 95(1):147-155. Abstract.

Kuang, Z. et al. 2003. Atmospheric deposition of pesticides to an agricultural watershed of the Chesapeake Bay. J. Environ. Qual. 32:1611-1622. Available on the internet at http://jeq.scijournals.org/cgi/reprint/32/5/1611

Kutz, F.W. et al. 1976. National pesticide monitoring networks. In: Lee, R.E., ed. Air Pollution from Pesticides and Agricultural Processes. Cleveland, OH. CRC Press, 95-136. Cited by ATSDR, 2006.

Lee, Chul-Ho et al. 2007. 8-Hydroxydeoxyguanosine levels in human leukocyte and urine according to exposure to organophosphorus pesticides and paraoxonase 1 genotype. Int. Arch. Occup. Environ. Health. 80:217-227. Available on the internet at http://www.springerlink.com/content/y011h11040514858/fulltext.pdf

Lee, S. et al. 2002. Community exposures to airborne agricultural pesticides in California: ranking of inhalation risks. Environ. Health Perspect. 110(12): 1175-1184. Available on the internet at http://www.ehponline.org/members/2002/110p1175-1184lee/EHP110p1175PDF.PDF

Leidy, R. B., et al. 1982. Concentration and movement of diazinon in air. J. Environ. Sci. & Health B. 17:311-319. Cited by WHO, 1998.

Lenhart, S.W. and M.M. Kawamoto. 1994. Residual air concentrations of pesticides in a commercial greenhouse. Appl. Occup. Environ. Hyg. 9(1):9-15. Cited by ATSDR, 2006.

Leonard JA & Yeary RA (1990) Exposure of workers using hand-held equipment during urban application of pesticides to trees and ornamental shrubs. Am Ind Hyg Assoc J. 51(11): 605-609. Cited by WHO, 1998.

Lewis, R.G. and R.E. Lee, Jr. 1976. Air pollution from pesticides: Sources, occurrence, and dispersion. In: Lee R.E. Jr., ed. Air pollution from pesticides and agricultural processes. Cleveland, OH: CRC Press, 5-50. Cited by ATSDR, 2006.

Li, J. et al. 2006. Observation of organochlorine pesticides in the air of the Mt. Everest region. Ecotoxicol. Environ. Saf. 63(1):33-41. Abstract.

Louie, P.K. and D.W. Sin. 2003. A preliminary investigation of persistent organic pollutants in ambient air in Hong Kong. Chemosphere. 52(9):1397-1403. Abstract.

Mackness, B. et al. 2003. Paraoxonase and susceptibility to organophosphorus poisoning in farmers dipping sheep. Pharmacogenetics. 13(2):81-88. Abstract.

Majewski, M.S. et al. 1998. Airborne pesticide residues along the Mississippi River. Environ. Sci. Technol. 32:3689-3698.

Martinez-Vidal, J.L. et al. 1997. Analysis of lindane, alpha- and beta-endosulfan and endosulfan sulfate in greenhouse air by gas chromatography. J. Chromatog. A. 765(1):99-108. Abstract.

Mast, M.A. et al. 2007. Current-use pesticides and organochlorine compounds in precipitation and lake sediment from two high-elevation national parks in the Western United States. Arch. Environ. Contam. Toxicol. 52:294-305. Available on the internet at http://www.springerlink.com/content/89484862kw010700/fulltext.pdf

McConnell, L. 2005. Environmental and Agricultural Factors Controlling Pesticide Volatilization, Transport, and Deposition. International Workshop on Crop Protection Chemistry in Latin America. Abstract. Available on the internet at http://www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=175902&pf=1

Moreau-Guigon, E. et al. 2007. Vertical and temporal distribution of persistent organic pollutants in Toronto. 1. Organochlorine pesticides. Environ. Sci. Technol. 41(7):2172-2177. Abstract.

Moya, J. 2004. Children’s behavior and physiology and how it affects exposure to environmental contaminants. Pediatrics. 113(4):996-1006. Available on the internet at http://pediatrics.aappublications.org/cgi/content/full/113/4/S1/996

NAS (U.S. National Academy of Sciences). 1999. Hormonally Active Agents in the Environment. Commission on Life Sciences. Page 60. Available on the internet at http://books.nap.edu/openbook.php?record_id=6029&page=60

NAS (U.S. National Academy of Sciences). 1994. Science and Judgment in Risk Assessment. Chapter 11. Aggregation. Available on the internet at http://www.nap.edu/openbook/030904894X/html/224.html

NAS (U.S. National Academy of Sciences). 1988. Complex Chemical Mixtures. Methods for In Vitro Toxicity Testing. National Academy Press. Washington, D.C. Available on the internet at http://www.nap.edu/catalog/1014.html

NAS (U.S. National Academy of Sciences). 1981. Aromatic Amines: An Assessment of the Biological and Environmental Effects. Committee on Amines. Board of Toxicology and Environmental Health Hazards. Assembly of Live Sciences. National Research Council. Washington, D.C. Pages 228 to 265. Available on the internet at http://books.nap.edu/catalog.php?record_id=664

NIOSH (U.S. National Institute for Occupational Safety and Health). 2007. Documentation for Immediately Dangerous to Life or Health Concentrations (IDLH): NIOSH Chemical Listing and Documentation of Revised IDLH Values (as of 3/1/95). Available on the internet at http://www.cdc.gov/niosh/idlh/intridl4.html

NIOSH (U.S. National Institute for Occupational Safety and Health). 1995a. Occupational Safety and Health Guideline for Endosulfan. Available on the internet at http://www.cdc.gov/niosh/pdfs/0251.pdf

NIOSH (U.S. National Institute for Occupational Safety and Health). 1995b. Occupational Safety and Health Guideline for Diazinon. Available on the internet at http://www.cdc.gov/niosh/pdfs/0181.pdf

NIOSH (U.S. National Institute for Occupational Safety and Health). 1994. Organophosphorus Pesticides. Method 5600. NIOSH Manual of Analytical Methods (NMAM), Fourth Edition, 8/15/94. Available on the internet at http://www.cdc.gov/niosh/nmam/pdfs/5600.pdf

NOAA (U.S. National Oceanic and Atmospheric Administration). 2007. Public Exposure Guidelines. Available on the internet at http://archive.orr.noaa.gov/cameo/locs/expguide.html

NPIC (U.S. National Pesticide Information Center). 1998. Diazinon. Available on the internet at http://npic.orst.edu/factsheets/diazinon.pdf

NRC (National Research Council). 2003. Gulf War and Health: Volume 2. Insecticides and Solvents. National Academy Press. Washington, D.C. Chapter 3. Insecticide Toxicology. Available on the internet at http://books.nap.edu/openbook.php?isbn=030908458X

NRC (National Research Council). 1993. Pesticides in the Diets of Infants and Children. National Academy Press. Washington, D.C. Available on the internet at http://books.nap.edu/catalog.php?record_id=2126

OEHHA (California Office of Environmental Health Hazard Assessment). 2001. Candidates for Proposition 65 Listing via the Authoritative Bodies Mechanism Found Not to Meet the Scientific Criteria (22 CCR Section 12306(g)): Diazinon (CAS No. 333-41-5). Available on the internet at http://www.oehha.ca.gov/prop65/pdf/dropout_rls8diazinon.pdf

O'Leary, K.A. et al. 2005. Genetic and other sources of variation in the activity of serum paraoxonase/ diazoxonase in humans: consequences for risk from exposure to diazinon. Pharmacogenet. Genomics. 15(1):51-60. Abstract.

OSHA (U.S. Occupational Safety & Health Administration). 1988. Endosulfan. Method number PV2023. Available on the internet at http://www.skcinc.com/nioshdbs/oshameth/2023/2023.html

Pandit, G.G. and S.K. Sahu. 2001. Gas exchange of OCPs across the air-water interface at the creek adjoining Mumbai harbour, India. J. Environ. Monit. 3:635-638. Available on the internet at http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b106215h&JournalCode=EM

PANNA (Pesticide Action Network North America). 2007. Drift Catching near South Woods Elementary School, Hastings, FL. Available on the internet at http://www.panna.org/campaigns/DCHastingsFL06.dv.html

Peck, A.M. and K.C. Hornbuckle. 2005. Gas-phase concentrations of current-use pesticides in Iowa. Environ. Sci. Technol. 39(9):2952-2959. Abstract.

Poet, T.S. et al. 2003. In vitro rat hepatic and intestinal metabolism of the organophosphate pesticides chlorpyrofos and diazinon. Toxicol. Sci. 72:193-200. Available on the internet at http://toxsci.oxfordjournals.org/cgi/reprint/72/2/193

Pozo, K. et al. 2006. Toward a global network for persistent organic pollutants in air: results from the GAPS study. Environ. Sci. Technol. 40(16):4867-4873. Abstract.

Pozo, K. et al. 2004. Passive-sampler derived air concentrations of persistent organic pollutants on a north-south transect in Chile. Environ. Sci. Technol. 38(24):6529-6537. Abstract.

Qiu, X. et al. 2004. Organochlorine pesticides in the air around the Taihu Lake, China. Environ. Sci. Technol. 38(5):1368-1374. Abstract.

Rice, C.P. et al. 2002. Volatilization of trifluralin, atrazine, metochlor, chlorpyrifos, anpha-endosulfan, and beta-endosulfan from freshly tilled soil. J. Agric. Food Chem. 50(14):4009-4017. Abstract.

Richter, E. D., et al. 1992. Illness and excretion of organophosphate metabolites four months after household pest extermination. Archives of Environmental Health 47:135-138. Available on the internet at http://www.encyclopedia.com/printable.aspx?id=1G1:12186080

Risher, J.F. and C.T. DeRosa. 1997. The precision, uses, and limitations of public health guidance values. Human & Eco. Risk Assess. 3(5):681-700. Available on the internet at http://www.atsdr.cdc.gov/mrls/articles/the_precision_uses_and_limitations_of_public_health_guidance_values.pdf

Scheuplein, R. et al. 2002. Differential sensitivity of children and adults to chemical toxicity. I. Biological basis. Reg. Tox. Pharmacol. 35:429-447. Available on the internet at http://www.tera.org/pubs/Scheuplein%202002.pdf

Scheyer, A. et al. 2005. Analysis of some organochlorine pesticides in an urban atmosphere (Strasbourg, east of France. Chemosphere. 58(11)1517-1524. Abstract.

Schomburg, C.J. et al. 1991. Pesticide occurrence and distribution in fog collected near Monterey, California. Environ. Sci. Technol. 25:155-160. Cited by ATSDR, 2006.

Seiber, J.N. et al. 1993. Air and fog deposition residues of four organophosphate insecticides used on dormant orchards in the San Joaquin Valley, California. Environ. Sci. Technol. 27(10):2236-2243. Cited by ATSDR, 2006.

Selene, C.H. et al. 1998. Minimal risk levels (MRLs) for hazardous substances. J. Technol., Environ. Toxicol., & Occup. Med. 7(1):1-24. Available on the internet at http://www.atsdr.cdc.gov/mrls/articles/minimal_risk_levels_for_hazardous_substances.pdf

Shen, L. et al. 2005. Atmospheric distribution and long-range transport behavior of organochlorine pesticides in North America. Environ. Sci. Technol. 39(2):409-420. Abstract.

Sigethy, S. et al. 1994. Comparing three approaches for deriving potency estimates for acute noncancer health effects: Phosgene- a case study. Society for Risk Analysis 1994 Annual Meeting. Abstract of Meeting Paper. Available on the internet at http://www.riskworld.com/abstract/1994/sraam94/ab4aa194.htm

Singh, N.D. et al. 2007. Citrinin and endosulfan induced maternal toxicity in pregnant Wistar rats: pathomorphological study. J. Appl. Toxicol. April 11 (Epub ahead of print). Abstract.

SJCSB (St. Johns County School Board). 2007. Report of Pesticide Testing Services South Woods Elementary School 4750 State Road 206 West Elkton, St. Johns County, Florida MACTEC Project No. 6741-07-3343. March 30, 2007. Available on the internet at http://www.panna.org/campaigns/DCHastingsFL06.dv.html

Soderquist, C.J. et al. 1975. Occurrence of trifluralin and its photoproducts in air. J. Agric. Food Chem. 23(2):304-309. Abstract.

U.S. Department of Defense. 2001. Environmental Exposure Report. Pesticides. Diazinon. Available on the internet at http://www.gulflink.osd.mil/retired/pest/pest_tabc8_5.htm

U.S. DOE (Department of Energy). 2007a. Temporary Emergency Exposure Limit (TEEL) database. Available on the internet at http://www.atlintl.com/DOE/teels/teel/search.html?msg=No%20input.%20Please%20re-enter.

U.S. DOE (Department of Energy). 2007b. Definitions for Different TEEL Levels. Available on the internet at http://www.eh.doe.gov/web/Chem_Safety/teeldef.html

U.S. DOE (Department of Energy). 2007c. Protective Action Criteria (AEGLs, ERPGs, or Rev. 22 TEELs for Chemicals of Concern 2007). Available on the internet at http://www.hss.energy.gov/HealthSafety/WSHP/chem_safety/teel/TEELsRev-22Introduction.pdf

U.S. DOE (Department of Energy). 2004. Table 2. Recommended TEELs Rev. 20 (original units). Available on the internet at http://www.eh.doe.gov/web/Chem_Safety/teel/TEELs_Rev20_Table2.pdf

USEPA. 2007a. Glossary. IRIS (Integrated Risk Information System). Available on the internet at on the internet at http://www.epa.gov/iris/gloss8.htm
USEPA. 2007b. Region 3 Risk Based Concentration Table. April 6, 2007. Available on the internet at http://www.epa.gov/reg3hwmd/risk/human/rbc/RBCapr07.pdf

USEPA. 2007c. Region 6 Human Health Medium Specific Screening Levels. Available on the internet at http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screenvalues.pdf

USEPA. 2007d. Important Exposure Factors for Children. An Analysis of Laboratory and Observational Field Data Characterizing Cumulative Exposure to Pesticides. Chapter 3. Air Concentration Measurements. Available on the internet at http://www.epa.gov/nerl/research/data/sections/exposure-factors-chapter3.pdf

USEPA. 2006a. Risk Assessment for Noncancer Effects. Technology Transfer Network. Air Toxics Website. Available on the internet at http://www.epa.gov/ttn/atw/toxsource/noncarcinogens.html

USEPA. 2006b. Approaches to Determining Internal Dose in Inhalation Risk Assessment at the US EPA. John Stanek and Gary L. Foureman. USEPA Science Forum, 2006. Available on the internet at http://www.epa.gov/ord/scienceforum/2006/poster_abstracts/disease_susceptibility/DS_Stanek.pdf

USEPA. 2006c. Development of Less than Chronic Reference Values in the IRIS Program. Dr. Robert Benson. U.S. Environmental Protection Agency, Region 8. Page 169-182. Available on the internet at http://www.epa.gov/waterscience/fstrac/presentations/day-2-fall-06.pdf

USEPA. 2006d. The Need for Inhalation Reference Concentration Values for Acute and Other “Less-than-lifetime” Exposure Durations. George M. Woodall and Gary L. Foureman. Available on the internet at http://www.epa.gov/sciforum/2006/pdfs/global_challenges_final_posters/GC-50_Woodall.pdf

USEPA. 2006e. Sources of Chronic Dose-Response Information. Technology Transfer Network. Air Toxics Website. Available on the internet at http://www.epa.gov/ttn/atw/toxsource/chronicsources.html

USEPA. 2006f. Prioritization of Data Sources for Chronic Exposure. Technology Transfer Network. Air Toxics Website. Available on the internet at http://ww.epa.gov/ttn/atw/toxsource/chronicpriority.html

USEPA. 2006g. Indian Harbor. Chapter 6. Pages 15, 21 and 91. Available on the internet at http://www.epa.gov/region5/sites/indianaharbor/pdfs/supplementalriskassessmentchapt6.pdf

USEPA. 2006h. A Preliminary Risk-based Screening Approach for Air Toxics Monitoring Data Sets. EPA-904-B-06-001. February 2006. Available on the internet at http://www.epa.gov/region04/air/airtoxic/Screening-041106-KM.pdf

USEPA, 2006i. Protecting Children. Available on the internet at http://www.epa.gov/pesticides/health/children.htm

USEPA. 2006j. A Framework for Assessing Health Risk of Environmental Exposures to Children. (Final). Available on the internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=158363

USEPA. 2006k. Revisions to the Child-Specific Exposures Handbook. Jacqueline Moya. U.S. Environmental Protection Agency. Pages 155-167. Available on the internet at http://www.epa.gov/waterscience/fstrac/presentations/day-2-fall-06.pdf

USEPA. 2005. Federal Register: August 10, 2005 (Volume 70, Number 153). Rules and Regulations. Pages 46705 – 46740. Available on the internet at http://a257.g.akamaitech.net/7/257/2422/01jan20051800/edocket.access.gpo.gov/2005/pdf/05-15840.pdf

USEPA. 2004a. Community Air Screening How-To Manual. A step-by-Step Guide to Using a Risk-Based Approach to Identify Priorities for Improving Outdoor Air Quality. EPA 744-B-04-001. Available on the internet at http://www.epa.gov/oppt/cahp/howto.html

USEPA, 2004b. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. USEPA Office of Emergency and Remedial Response. Endosulfan, table on page B-2. Februrary 22, 2004. Available on the internet at http://www.epa.gov/swerrims/riskassessment/airmodel/pdf/guide.pdf

USEPA. 2004c. Region 9. Preliminary Remediation Goals Table. Available on the internet at http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf

USEPA. 2004d. Interim Reregistration Eligibility Decision. Diazinon. EPA 738-R-04-006. May 2004. Page 14. Available on the internet at http://envirocancer.cornell.edu/turf/pdf/diazinon_ired.pdf

USEPA. 2004e. Developing Relative Potency Factors for Pesticide Mixtures: Biostatistical Analyses of Joint Dose-Response. Vol. 69. No. 4. Wednesday, January 7, 2004. pp1-115. EPA/600/R-03-052F. Available on the internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=66273

USEPA. 2003a. Region/ORD Workshop on Inhalation Risk Assessment: A Superfund Focus. September 9-12, 2003. Washington, D.C. http://www.epa.gov/osp/regions/inhal_rep.pdf

USEPA. 2003b. Developing Relative Potency Factors for Pesticide Mixtures: Biostatistical Analyses of Joint Dose-Response. EPA/600/R-03/052. Sept. 2003. Available on the internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=66273

USEPA. 2002a. Endosulfan: Reevaluation of the HED Risk Assessment for the Endosulfan Reregistration Eligibility Decision (RED) Document. May 30, 2002.

USEPA. 2002b. Reregistration Eligibility Decision for Endosulfan. EPA 738-R-02-013. Available on the internet at http://www.epa.gov/oppsrrd1/REDs/endosulfan_red.pdf

USEPA. 2002c. A Review of the Reference Dose and Reference Concentration Process. Available on the internet at http://www.epa.gov/IRIS/RFD_FINAL%5B1%5D.pdf

USEPA. 2002d. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Instrusion Guidance). November 2002. EPA530-D-02-004. Table 2A, page 58 and Table D12, page 122 of the document located on the internet at http://www.epa.gov/correctiveaction/eis/vapor/complete.pdf

USEPA. 2002e. Protecting Children from Pesticides. Available on the internet at http://www.epa.gov/pesticides/factsheets/kidpesticide.htm

USEPA. 2000a. Human Health Risk Assessment. Diazinon. December 5, 2000. Reregistration Branch 3, Health Effects Division, Office of Pesticide Programs.

USEPA. 2000b. National Air Toxics Program: The Integrated Urban Strategy Report to Congress. Appendix: HAP Profiles (EPA 453/R-99-007). Page A-24. Available on the internet at http://www.epa.gov/ttn/atw/urban/natpapp.pdf

USEPA. 2000c. Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. EPA 630/R-00/002. Available on the internet at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=22567

USEPA. 1999a. Technology Transfer Network. 1999 National-Scale Air Toxics Assessment. Health Effects Criteria. Available on the internet at http://www.epa.gov/ttn/atw/nata1999/nsata99.html

USEPA. 1999b. Guidance for Conducting Health Risk Assessment of Chemical Mixtures. NCEA-C-0148. April 1999. Available on the internet at http://www.epa.gov/NCEA/pdfs/mixtures.pdf

USEPA. 1996. Trifluralin. R.E.D. Facts. EPA-738-F-95-035. April 1996. Available on the internet at http://www.epa.gov/REDs/factsheets/0179fact.pdf

USEPA. 1995. Policy on Evaluating Risk to Children. Available on the internet at http://www.epa.gov/osa/spc/2poleval.htm

USEPA. 1994. Methods for Derivation of Inhalation Reference Concentrations and Application of Inhalation Dosimetry. EPA/600/8-90/066F. Office of Research and Development, Office of Health and Environmental Assessment. Washington, D.C. Available on the internet at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=71993

USEPA (U.S. Environmental Protection Agency). 1988. Technical Support Document on Risk Assessment of Chemical Mixtures. EPA-600/8-90/064. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development. Cited by NAS, 1994. Available on the internet at http://www.epa.gov/cgi-bin/claritgw?op-Display&document=clserv:ORD:0325;&rank=4&template=epa

USEPA. 1986. 1986 Guidelines for the Health Risk Assessment of Chemical Mixtures. Available on the internet at http://cfpub.epa.gov/ncea/raf/recordisplay.cfm?deid=22567

Van Drooge, B.L. et al. 2004. Atmospheric semivolatile organochlorine compounds in European high-mountain areas (central Pyrenees and high Tatras). Environ. Sci. Technol. 38(13):3525-3532. Abstract.

Wachs, T., et al. 1983. Concentration of diazinon in air of a retail garden store. Bull. Environ. Contam. Toxicol. 31:582-584. Cited by ATSDR, 2006.

Waite, D.T. et al. 2004. Environmental concentrations of agricultural herbicides in Saskatchewan, Canada: Bromoxynil, dicamba, diclofop, MCPA, and trifluralin. J. Environ. Qual. 33:1616-1628. Available on the internet at http://jeq.scijournals.org/cgi/reprint/33/5/1616

Weber, J. et al. 2006. Endosulfan and gamma-HCH in the arctic: an assessment of surface seawater concentrations and air-sea exchange. Environ. Sci. Technol. 40(24):7570-7576. Abstract.

Wester, R.C. et al. 1993. Percutaneous absorption of diazinon in humans. Food Chem. Toxicol. 31(8):569-572. Abstract.

Wheelock, C.E. et al. 2005. Overview of carboxylesterases and their role in the metabolism of insecticides. J. Pestic. Sci. 30(2):75-83. Available on the internet at http://www.jstage.jst.go.jp/article/jpestics/30/2/75/_pdf

White, A.W. et al. 1977. Trifluralin volatilization losses from a soybean field. J. Environ. Qual. 6(1):105-110.

White, L.M. et al. 2006. Ambient air concentrations of pesticides used in potato cultivation in Prince Edward Island, Canada. Pest. Manag. Sci. 62(2):126-136. Abstract.

Whitmore, R. W., et al. 1994. Non-occupational exposures to pesticides for residents of two U.S. cities. Arch. of Environ. Contam. Toxicol. 26:47-59.

WHO (World Health Organization). 2004. The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification. International Programme on Chemical Safety. Available on the internet at http://www.inchem.org/documents/pds/pdsother/class.pdf

WHO (World Health Organization). 2001. Diazinon (addendum). Pesticide Residues in Food 2001. Toxicological Evaluations. Available on the internet at http://www.inchem.org/documents/jmpr/jmpmono/2001pr03.htm

WHO (World Health Organization). 1998. Diazinon. International Programme on Chemical Safety. Environmental Health Criteria 198. Available on the internet at http://www.inchem.org/documents/ehc/ehc/ehc198.htm#SubSectionNumber:7.2.2

WHO (World Health Organization). 1990. Environmental Health Criteria 104. Principles for the Toxicological Assessment of Pesticide Residues in Food. Available on the internet at http://www.inchem.org/documents/ehc/ehc/ehc104.htm

Whyatt, R.M. et al. 2003. Contemporary-use pesticides in personal air samples during pregnancy and blood samples at delivery among urban minority mothers and newborns. Environ. Health Perspect. 111(5):749-756. Available on the internet at http://www.ehponline.org/members/2003/5768/5768.pdf

Williams, P.R.D. et al. 2006. VCCEP Pilot: Progress on evaluating children's risks and data needs. Risk Analysis. 26(3):781-801. Available on the internet at http://www.tera.org/pubs/williams%20et%20al%20accepted.pdf

Woodall, G.M. 2005. EPA Reference Values: Regulatory Context. Leland Urban Air Toxics Research Center. October 18, 2005 powerpoint presentation. Available on the internet at http://www.sph.uth.tmc.edu/mleland/Pages/Workshop/2005%20Presentation/session%202/woodall.ppt#1

Wilbur, S.B. 1998. Health effects classification and its role in the derivation of minimal risk levels: respiratory effects. J. Clean Technol., Environ. Toxicol., & Occup. Med. 7(3):233-249. Available on the internet at http://www.atsdr.cdc.gov/mrls/articles/health_classification_and_its_role_in_the_derivation_of_mrl_respiratory_effects.pdf

Wilson, N.K. et al. 2001. Levels of persistent organic pollutants in several child day care centers. J. Expo. Anal. Environ. Epidemiol. 11:449-458. Available on the internet at http://www.nature.com/jea/journal/v11/n6/pdf/7500190a.pdf

Wright, C. G., and Leidy, R. B. 1980. Air samples in vehicles and buildings turn up only very low levels of organic phosphate insecticides. Pest Control, 22-26: 68.

Wright, C. G., and Leidy, R. B. 1980. Insecticide residues in the air of buildings and pest control vehicles. Bulletin of Environmental Contamination and Toxicology 24:582-589.

28,119-121.

Zabik, J.M. and J.N. Seiber. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. J. Envir. Qual. 22:80-90. Cited by ATSDR, 2006.

VII. Appendices

A. Studies on Environmental Levels of Endosulfan

Endosulfan has been detected in air at various levels in numerous studies and it is reportedly one of the most abundant and ubiquitous organochlorine pesticides in the North American atmosphere (Shen et al., 2005). Endosulfan is moderately persistent in the soil environment, with a reported average field half-life of 50 days, although on most fruits and vegetables, about half is lost within 3 to 7 days (EXTOXNET, 2007).

In South Florida, field sites were established at the Everglades National Park, Adam's Key in Biscayne National Park, and the Tropical Research and Education Center at University of Florida in Homestead. Endosulfan was consistently detected year round in weekly air samples, with a maximum value of 90 ng/m^3 (Hapeman et al., 2005).

Low levels of endosulfan have been detected in outdoor ambient air in remote locations, far from agricultural activity, demonstrating that endosulfan is fairly persistent in the environment and is capable of long range transport (Belzer et al., 1998; Bidleman et al., 1995; Buehler et al., 2004; Gouin et al., 2005; Harner et al., 2006; Harner et al., 2005; Kuang et al., 2003; Louie and Sin, 2003; Moreau-Guigon et al., 2007; Pandit and Sahu, 2001; Pozo et al., 2006; Pozo et al., 2004; Qiu et al., 2004; Scheyer et al., 2005; NAS, 1999). Endosulfan and its degradates have even been detected in air from Mount Everest (Li et al., 2006), the central Pyrenees, and high Tatras (van Drooge et al., 2004). Its presence in arctic air and seawater (Weber et al., 2006), snow and other environmental matrices at high elevations in mountainous regions of the Western U.S. indicates that it is ubiquitous at low levels on a global scale as a result of atmospheric deposition (Mast et al., 2007).

Endosulfan levels in air have also been reported at widely varying concentrations in different agricultural settings (Hatzilazarou et al., 2004; Martinez-Vidal et al., 1997; White et al., 2006; Goel et al., 2005).

Studies have also reported finding endosulfan in indoor air (Bouvier et al., 2006).

Endosulfan Levels Reported in Air from Selected Studies

Environmental Setting	Reported Range of Air Concentrations (ng/m^3)	Reference
Greenhouse air 2-hours post application	10,000	Hatzilazarou et al., 2004
Greenhouse air 6-days post application	410	
Outdoor urban/agricultural air at Everglades, Biscayne National Park, Homestead	90	Hapeman et al., 2005
Outdoor air of agricultural area in British Columbia, Agassiz site	Endosulfan I: mean 0.708(0.061 to 2.629)	Belzer et al., 1998
	Endosulfan II: mean 0.253 (0.075 to 0.548)	
Outdoor air of agricultural area in British Columbia, Abbotsford site	Endosulfan I: mean 0.620 (0.050 to 2.309)	
	Endosulfan II: mean 0.184 (0.035 to 0.652)	
Outdoor ambient air in 16 states	Endosulfan I: mean 4.3, maximum 2257	Kutz et al., 1976/ HSDB 2007
	Endosulfan II: mean 0.1, maximum 54.5	
Outdoor air in agricultural area in region of Chesapeake Bay	Endosulfan I: median 0.068 (0.011 to 0.68)	Kuang et al., 2003
	Endosulfan II: median 0.026 (0.0053 to 0.120)	
Outdoor agricultural areas in the Great Lakes Basin	Endosulfan I: 0.04 to 1.09	Gouin et al., 2005
Outdoor agricultural areas in the Great Lakes Basin, 1970's	Endosulfan I and II: approx. 1 to 2	Eisenrich et al., 1981; Hayes and Laws, 1991
Outdoor air in Columbia South Carolina	Endosulfan I: mean 0.078	Bidleman, 1981/ HSDB 2007
Outdoor air in North Atlantic, Arabian Sea, Persian Gulf, and the Red Sea	0.007 to 0.021	Bidleman et al.,1982/ Hayes and Laws, 1991
Outdoor air above seawater over Resolute Bay, Canada	0.004	Bidleman et al., 1995/ NAS, 1999
Outdoor ambient air in Hong Kong	Endosulfan I: 0.02 to 0.23	Louie and Sin, 2003
Outdoor air in an agricultural area of Taihu Lake Region, China	Endosulfan I: mean 0.053	Qiu et al., 2004
Outdoor ambient air in Bloomington, In in 1994	0.012 to 0.041	Wallace and Hites, 1996/ HSDB 2007
Outdoor ambient air in Bloomington, In from 1991 to 1992	Endosulfan I: mean 0.086	Burgoyne, 1993/ ATSDR 2000
Outdoor ambient air, urban/rural British Columbia 2001	0.005 to 0.15	Harner et al., 2005

Outdoor rural air in Ontario 1988 to 1989	mean 3.7	Hoff et al., 1992/ ATSDR 2000
Outdoor ambient air in Chile	0.0035 to 0.099	Pozo et al., 2004
Outdoor background air Global Atmospheric Passive Sampling	Endosulfan I: geo. mean range 0.005 to 0.058	Pozo et al., 2006; Harner et al., 2006
Outdoor air in Mt. Everest region at 4400 meters above sea level	Endosulfan I: mean 0.028	Li et al., 2006
Outdoor air in coastal area of India, Mumbai harbour	Endosulfan I: 0.001 to 0.0016	Pandit and Sahu, 2001
Outdoor European high-mountain areas	0.004 to 0.01	van Drooge et al., 2004

The highest concentration of endosulfan in air reported by PANNA was 626 ng/ m^3
The mean concentration of endosulfan in air reported by PANNA was 278 ng/ m^3

B. Studies on Environmental Levels of Diazinon

Diazinon has been detected in air at various levels in numerous studies (Belzer et al., 1998; Kuang et al., 2003; Seiber et al., 1993; ATSDR, 2006).

Reportedly, up to 25% of applied diazinon can undergo long-term volatilization to the air from the surface where it was applied, although volatilization quickly declines to low levels (ATSDR, 2006; Glotfelty et al., 1990a; Glotfelty et al., 1990b; Schomburg et al., 1991; Seiber et al., 1993; Zabik and Seiber, 1993).

Diazinon can be transported moderate distances in the air from its original point of use, and it has been detected at low levels, for example, at an elevation of 533 meters in the Sierra Nevada Mountains (Zabik and Seiber, 1993).

From 1986 through 1988, 24-hour indoor and outdoor air samples were collected in Jacksonville, Florida, and the reported mean diazinon concentrations were 85.7 to 420.7 ng/m3 in indoor air and 1.1 to 13.8 ng/m3 in outdoor air (Whitmore et al. 1994). A subsequent study in Jacksonville reported the median concentration of diazinon in indoor air at 73 ng/m3 in the summer and 21 ng/m3 in the winter (Gordon et al., 1999; HSDB, 2007). Diazinon was detected in 80% of samples collected in ambient suburban air in Miami, Florida (Kutz et al. 1976), at levels in the low nanogram per cubic meter range, which is consistent with that found in South Florida in other studies (Lewis and Lee 1976). In a study by the U.S. Department of Agriculture, weekly air samples taken in South Florida during the winter, and diazinon was reportedly present at a maximum concentration of 90 ng/m3 (Hapeman et al., 2005).

Diazinon was detected in 100% of air samples collected from over the Mississippi River from New Orleans, Louisiana, to St. Paul, Minnesota, during the first 10 days of June 1994, although the mean concentration in that study was only 0.08 ng/m^3 (Majewski et al., 1998). Nationwide, diazinon was detected in 48% of 123 urban air samples collected in 10 U.S. cities during 1980 (Carey and Kutz 1985).

Following a 4-hour cold fogging application in a greenhouse of a pesticide formulation containing diazinon, levels in air reached 3,030,000 ng/m^3 (Lenhart and Kawamoto, 1994). The workshop air in a production facility in Hungary contained 450,000 ng/m^3 of diazinon. Workers in that facility reportedly had a moderately increased number of chromatid-type aberrations compared to control groups (Kiraly et al., 1979; HSDB, 2007). Eight-hour personal breathing air sampling of 13 pest control operators gave a mean diazinon concentration of 6,290 ng/m^3 to as high as 41,000 ng/m^3. These workers were also exposed to dichlorvos at levels up to 131,000 ng/m^3 and chlorpyrifos at levels up to 27,600 ng/m^3. Compared to control groups, these workers had statistically significant inhibition of plasma acetylcholinesterase (AChE), but there were no significant differences in the mean red blood cell ACheE values, and physical examinations detected no apparent toxic effects in the study group (Hayes et al., 1980; HSDB, 2007).

Airborne and surface concentrations of diazinon, chlorpyrifos (Dursban), and bendiocarb (Ficam) were measured at intervals up to 10 days after broadcast spray application onto the floors of seven offices. Airborne concentrations of diazinon peaked 4 hr after application at 163,000 ng/m^3 of air sampled (Currie et al., 1990).

The average concentration of diazinon in the air of a retail garden store was 3,400 ng/m^3 (Wachs et al., 1983).

In the Arizona pilot study for the National Human Exposure Assessment Survey (NHEXAS), the concentration of diazinon in indoor residential air was found to be as high as 20,500 ng/m^3 (Gordon et al., 1999).

Five months after a house had been treated with diazinon, concentrations of diazinon in the air were between 5,000 and 27,000 ng/m^3, and levels of diazinon were elevated on clothes of family members and on the surfaces of the home. The family living in the home complained of headache, vomiting, fatigue, and chest heaviness (Richter et al., 1992).

An investigation was conducted to determine worker exposure to airborne pesticides during tree and ornamental shrub applications using hand-held equipment during an entire work shift. Employee exposure data were collected at 23 locations for 3 consecutive years. Diazinon as well as other pesticides (*e.g.*, acephate, benomyl, carbaryl, chlorothalonil, and dicofol) were measured. Levels in air were below that recommended by OSHA and NIOSH, and were in the range of less than 0.001 to as high as 0.040 mg/m^3 (1,000 to 40,000 ng/m^3; Leonard and Yeary, 1990).

Wilson et al. (2001) reported finding diazinon levels in the indoor air at ten North Carolina child day care centers to be at a mean level of 15 ng/m^3, with a maximum of 62.4 ng/m^3.

A recent assessment of children's exposure to diazinon indicated that ingestion rather than inhalation was the dominant route of exposure, although diazinon was reportedly detected in less than 1% of drinking water (Clayton et al., 2003; Bradman and Whyatt, 2005).

Diazinon Levels Reported in Air from Selected Studies

Environmental Setting	Reported Range of Air Concentrations (ng/m^3)	Reference
Indoor office air 4-hours post-application	29,000 to 163,000	Currie et al., 1990/ U.K. PSD, 1991
Indoor office air 10-days post-application	8,000	
Mean indoor air concentration up to 24-hr post-application based on monitoring data from 3 studies	37,800 mean	EPA, 2000
Personal air monitors used by pesticide applicators, 8-hour average values	6,290 mean (800 to 41,000)	Richter, 1992/ Hayes, 1980
Indoor air up to 21 days following crack and crevice treatment	400 to 38,000	Leidy et al., 1982
Indoor residential air Arizona NHEXAS study	20,500 maxmimum	Gordon et al., 1999/ CalARB, 2005
Indoor air in a retail garden store, 14 hour average	3,400	Wachs et al., 1983
Indoor air at a junior high school	2,400 maximum	NIOSH, 1991
Greenhouse air	5,000 to 10,000	Tharr, 1995
Indoor air at an animal laboratory facility	500 to 3,000	Williams et al., 1987
Indoor air in an office at a pest control company	30 to 600	Wright and Leidy, 1980/ Hayes and Laws, 1991
Indoor air at a college dormatory, North Carolina	approx. 1,000	Wright et al., 1981/ Hayes and Laws, 1991
EPA NOPES Jacksonville indoor air, summertime	421 mean (15 to 13,700)	CalARB, 2005/ Whitmore et al., 1994
Personal air monitors, 48-hour avg., used by pregnant New York women, indoor residential air	129 mean (2 to 6,010)	Whyatt et al., 2003
Indoor air at a bank in Pennsylvania	60 to 130	NIOSH, 2007
Outdoor urban/agric. air, Everglades, Biscayne National Park, Homestead, FL	90 maximum weekly average	Hapeman et al., 2005

Outdoor air in the Everglades National Park in 1973-1974	0.6 mean, maximum 1.9	Lewis and Lee, 1976/ ATSDR 2006
Outdoor air in urban Miami in 1973-1974	1.5 mean, maximum 3.3	
Outdoor agricultural area Parlier, California near fruit and nut orchards	mean 76.8 (up to 100 or more)	Selber et al., 1993/ ATSDR 2006
Outdoor agricultural area Fresno County, California, several ft. up to 3 mi. from field	mean 17	Harnly et al., 2005
Outdoor ambient air in Fresno County, at least 0.4 km from agricultural applications	maximum 35.7	CalEPA, 1993
Outdoor agricultural area, Franklin Field Airport, California	mean 4 (0.2 to 19.11)	Majewksi and Baston, 2002
Outdoor agricultural area, Sacramento Int. Airport, California	mean 7 (0.41 to 112.16)	
Outdoor urban area, Sacramento Metropolitan area	mean 2.4 (0.01 to 12.25	
Outdoor air of agricultural area in British Columbia, Agassiz site	mean 0.484 (0.136 to 1.186)	Belzer et al., 1998
Outdoor air of agricultural area in British Columbia, Abbotsford site	mean 4.664 (0.072 to 42.688)	
Outdoor air in Sierra Nevada Mountains at elevation of 114 meters	0.013 to 10	Zabik and Seiber, 1993/ ATSDR 2006
Outdoor ambient air in 14 states from 1970 to 1972	mean 2.5, maximum 62.2	Kutz et al., 1976/ ATSDR 2006/ HSDB 2007
Outdoor ambient air in 10 U.S. cities during 1980	mean 2.1, maximum 23	Carey and Kutz, 1985/ ATSDR 2006
Outdoor ambient suburban air in Miami, Florida	3.9	Kutz et al., 1976/ ATSDR 2006
Outdoor ambient suburban air in Jackson, Mississippi	2	
Outdoor ambient suburban air in Fort Collins, Colorado	2.2	
Outdoor air over the Mississippi River from New Orleans to St. Paul, 1994, 24-hour sampling	mean 0.08, maximum 0.36	Majewski et al., 1998/ ATSDR 2006
Outdoor urban air, Kitakyushi City, Japan in 1992	0.05	Haraguchi et al., 1994/ HSDB 2007

The highest concentration of diazinon in air reported by PANNA was 897ng/m^3
The mean concentration of diazinon in air reported by PANNA was 311 ng/m^3
Nationwide, diazinon was detected in 48% of urban air samples collected in 10 U.S. cities during 1980 (ATSDR 2006/ Carey and Kutz, 1985).
Individual exposure to diazinon in a residential setting was reported to be at a mean inhalation intake of 4204 ng/h/m^3 (Moschandreas et al., 2001).

C. Studies on Environmental Levels of Trifluralin

Trifluralin has been detected in air at low levels in outdoor ambient air (Kuang et al., 2003). An early study reported finding trifluralin in air above agricultural fields, and it was determined that rates of volatilization depend on soil moisture and other factors (Soderquist et al., 1975).

A 1981 report by the U.S. National Academy of Sciences (NAS, 1981) concluded that trifluralin is not an especially persistent chemical. Regarding the volatilization of trifluralin, the report stated the following: “Although the rate of volatilization of trifluralin depends to a great extent on the method of its application, such dissipation provides a significant potential exposure route for persons living downwind of treated fields. If trifluralin is applied to the soil surface, up to 90% of the compound may be volatilized within 2-3 days of application. If it is incorporated into the soil, volatilization losses can be as little as 3% or 4% in 90 days.” However, the report added, “Exposure of persons living downwind of sprayed fields is somewhat reduced because trifluralin is subject to fairly rapid photochemical decomposition. Measurements of trifluralin degradation in air indicate a half-life of 20 minutes under midday summer sunlight conditions.”

At a height of 20 cm above the ground in an agricultural field, the maximum concentration of trifluralin in air was initially 16,500 ng/m^3, which decreased to a maximum level of 3,400 ng/m3 by the second day after application, and was less than 100 ng/m^3 by day 35 after the application. Interestingly, nighttime levels in that study were typically greater than daytime levels, in some cases nearly as much as two orders of magnitude greater, although the air levels at night were not always greater than daytime levels and were greatly affected by rain events and soil moisture (White et al., 1977).

Volatilization may represent a major dissipation pathway for trifluralin Volatilization fluxes for trifluralin were relatively high (1900 ng/m^{2}s immediately after application to bare soil, but decreased down to 100 ng/m^{2}s in the following 24 hours. The concentration in air was negligible over the next few days as the trifluralin became incorporated into the soil (Bedos et al., 2006).

Volatile profiles of six agricultural pesticides were measured for 20 days following treatment to freshly tilled soil in Maryland (Rice et al., 2002). The order of the volatile flux losses in that study was trifluralin> alpha-endosulfan>chlorpyrifos> metolachlor> atrazine> beta-endosulfan. The magnitude of the losses ranged from 14.1% of nominal applied amounts of trifluralin to 2.5% of beta-endosulfan. The majority of the losses occurred within 4 days of treatment.

Pesticides were measured in urban, rural, and suburban sites in eastern Iowan during 2000 to 2002 (Peck and Hornbuckle, 2005). Trifluralin was the second most-often detected pesticide, and was found in 78% of the air samples, although the average concentration was only 0.52 ng/m^3. These results are consistent with regional ambient air measurements in Saskatchewan, Canada, in which trifluralin was the most frequently detected herbicide in air, detected in 79% of the samples, although at a very low mean concentration of 0.68 ng/m^3 (Waite et al., 2004).

Other researchers reported that trifluralin losses into the atmosphere can be as high as 25% of that applied (Grover et al., 1997). Maximum trifluralin levels in the air above treated fields were reported to be in the range of 2,000 to 3,000 ng/m^3 following application. However, trifluralin levels in the ambient air of intense use areas rapidly dissipated to less than 100 ng/m^3. Trifluralin may readily degrade under sunlight in all environmental media, with half lives ranging from minutes to several months, depending on the substrate, although it may have some potential for long-range transport and may be relatively persistent at extremely low levels in the air (*e.g.*, < 0.1 ng/m^3) of remote regions where trifluralin is not used.

Trifluralin was detected in all of the soil samples from 32 cotton fields in Georgia and South Carolina at concentrations ranging from 1 to 548 μg/kg dry weight (Kannan et al., 2003). Researchers in that study concluded that it is likely that trifluralin volatizes from soil and is transported over long distances.

Trifluralin Levels Reported in Air from Selected Studies

Environmental Setting	Reported Range of Air Concentrations (ng/m^3)	Reference
Outdoor air in Watkinsville, Georgia, 20 cm above soil during application, 3 to 12 hour sampling time	maximum 16,500	White et al., 1977
Outdoor air in Watkinsville, Georgia, 20 cm above soil 2 days after application, 3 to 12 hour sampling time	maximum 3,400	
Outdoor air in Watkinsville, Georgia, 20 cm above soil 6 days after application, 3 to 12 hour sampling time	maximum 1,150	
Outdoor air in Watkinsville, Georgia, 20 cm above soil 18 days after application, 3 to 12 hour sampling time	maximum 470	
Outdoor air in Watkinsville, Georgia, 20 cm above soil 35 days after application, 3 to 12 hour sampling time	maximum 100	
Outdoor air 275 meters from a trifluralin formulation plant in TN	mean 10.2, max 30.3	Lewis and Lee, 1976/ HSDB 2007
Outdoor air Perkin, Illinois 1980	1.3 to 5	Carey and Kutz, 1985/ HSDB 2007
Outdoor air in Saskatchewan agricultural region	0.68 mean, 3.31 maximum	Waite et al., 2004
Outdoor air 14 states 1970-1972	mean range 0.1 to 0.2	Kutz et al., 1976/ HSDB 2007
Outdoor air above treated agricultural fields	maximum 2,000 to 3,000	Grover et al., 1997
Outdoor air in intensive use areas	<100	
Outdoor air in remote nonuse areas	<0.1	
Outdoor air	mean 0.52	Peck and Hornbuckle, 2005

The highest concentration of trifluralin in air reported by PANNA was 376 ng/m^3
The mean concentration of trifluralin in air reported by PANNA was 84 ng/m^3