UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

3/7/94

1994

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

SUBJECT: Revised Occupational and Residential Risk Assessment for the Triazines

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Attached is an updated occupational and residential risk assessment for atrazine, simazine and cyanazine. HED has revised the existing exposure and risk assessments for atrazine and simazine to incorporate new hazard and exposure information. In addition, cancer risk estimates for cyanazine use on field corn are also provided. The cyanazine risk estimates are based on exposure assessments previously completed for atrazine.

The excess individual cancer risk estimates range from 10^{-6} to 10^{-2} for typical use of atrazine, simazine and cyanazine. The use of closed pour loading systems and/or closed cabs during application significantly reduces the cancer risks to individuals involved in the application of these herbicides. However, neither closed loading nor closed cabs are required on current atrazine, simazine or cyanazine product labels. Margins of exposure for short-term and intermediate exposure scenarios have been reevaluated and all MOEs now exceed 100.

Attachment

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HED Triazine Team Members: (Members responsible for review of technical accuracy, occupational and residential exposure estimates, issues presented and policies as relevant to this risk assessment.)

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Revised Occupational and Residential Risk Assessment for the Triazines

I. BACKGROUND

In October 1989, the Health Effects Division estimated the subchronic (cardiotoxicity) and chronic (carcinogenicity) risks to individuals mixing, loading and applying (M/L/As) atrazine.[1] HED also estimated the exposure to handlers involved in the application of simazine.[2] However, a formal document assessing the simazine cancer risks to M/L/As has never been completed. Cyanazine was the subject of a Special Review completed in 1988, but cancer risks to M/L/As were not estimated because teratogenicity (an acute effect) was the focus of the Agency's regulatory action. Because comparable risk assessments are not available, HED has used existing hazard and exposure information to provide risk estimates for atrazine, simazine and cyanazine. This risk assessment is not a comprehensive assessment addressing all uses of the triazines. Rather, HED has provided risk estimates capturing the major crops and application methods potentially resulting in the highest exposure. HED has also updated previous assessments to account for new hazard and exposure information. These changes are discussed below.

II. REVISIONS TO OCCUPATIONAL/RESIDENTIAL RISK ASSESSMENTS

A. Revised Cardiotoxicity MOEs for Atrazine

HED calculated margins of exposure (MOEs) for workers mixing, loading and applying atrazine based on cardiotoxicity.[1] The no-observed-effect-level (NOEL) used in the MOE calculations was derived from a 1-year dog feeding study. HED's latest evaluation of the study concludes that cardiotoxicity (i.e., EKG changes and cardiac lesions) occurred at the highest dose tested - 34 mg/kg/day.[3] A NOEL for cardiotoxicity was subsequently established at 5.0 mg/kg/day and used to calculate MOEs.

In calculating MOEs for cardiotoxicity, HED adjusted for dermal absorption because the NOEL was derived from an oral feeding study and the primary route of worker exposure is via contact with the skin (i.e., dermal). This approach is consistent with Agency policy and it assumes that the systemic load (i.e., bioavailable dose) is the same from both oral and dermal routes of exposure. The registrants have submitted kinetics data allowing HED to more accurately characterize MOEs based on cardiotoxicity. The data enabled HED to compare peak blood concentration data from oral toxicity and dermal absorption studies.[4] Comparing the blood concentrations following administration by different routes provides a more accurate method of assessing risk because it accounts for absorption, distribution and excretion, which can be different depending upon the route of administration. HED believes this method provides a more realistic assessment of the likelihood of occurrence of toxic effects from relatively short-term exposures. The atrazine data indicate that maximum blood levels following dermal exposure were several orders of magnitude lower than following ingestion of the chemical at similar doses. HED has derived a route-to-route comparison factor (CF) from the peak blood concentration data to be used in MOE calculations.

B. Revised Use Information for Atrazine and Simazine

HED based previous atrazine and simazine exposure assessments on use related exposure information provided by the Biological and Economics Analysis Division (BEAD).[5,6] BEAD recently reviewed this information and did not identify any changes in use practices that would significantly affect previous exposure assessments. However, BEAD did verify that the typical application rate for atrazine use on field corn is closer to 1.2 lb. a.i./acre rather than 2 lb. a.i./acre used in previous assessments.[7] BEAD staff have also indicated that the typical application rate for atrazine in sorghum is less than 1.0 lb. a.i./acre, while simazine is typically applied to corn at 1.1 lb. a.i./acre.[8] These rates are significantly lower than those used in previous assessments and will be used to update the atrazine and simazine exposure assessments.

C. Additional Personal Protective Equipment for Simazine

The Occupational and Residential Exposure Branch's (OREB) previous exposure assessment for simazine, completed in 1989, assumed that all handlers wear long sleeve shirts, long pants and boots, but that only individuals mixing and loading simazine actually wear chemical resistant gloves.[2] The 1989 assessment also accounted for use of mechanical transfer systems for commercial mixer/loaders, but did not estimate the exposure of applicators operating equipment with closed cabs. HED has expanded the simazine risk assessment to address open versus closed loading systems and application from open versus closed cab tractors. In addition, HED has estimated cancer risks to M/L/As using aerial equipment to apply simazine to field corn. The exposure estimates for closed loading systems, closed cab tractors and aerial application are based on assessments previously conducted for atrazine.[9-11]

D. Cancer Risk Estimates for Cyanazine Use on Field Corn

As mentioned above, cancer risks to M/L/As were not estimated in the previous cyanazine Special Review because teratogenicity (an acute effect) was the focus of the Agency's concerns and cyanazine had not yet been reviewed by the HED Carcinogenicity Peer Review Committee. This assessment includes cancer risk estimates for M/L/As involved in cyanazine application to corn, the predominant use site. Once again, the risk estimates are based on exposure assessments completed for atrazine because both pesticides are applied in a similar fashion to field corn.

III. HAZARD IDENTIFICATION/DOSE-RESPONSE ASSESSMENT

The primary toxicological endpoint of concern for the triazines is carcinogenicity. HED also identified cardiotoxicity as a potential concern for atrazine.

A. Atrazine

1. Cardiotoxicity

In 1987, the registrants submitted a 1-year chronic dog feeding study in which atrazine was administered at doses of 0, 15, 150 or 1000 ppm, which correspond to doses of 0, 0.5, 5 or 34 mg/kg/day. The study authors concluded that treatment-related effects were found only at the highest dose tested. These effects were EKG alterations and cardiac lesions. In its 1988 review of this study, HED determined that there was a treatment-related effect at the mid-dose level and concluded that the NOEL for cardiac toxicity was 0.5 mg/kg/day. The cardiac effects were observed at 85 days (the earliest point of sampling) in this study.

A Grassley-Allen letter was sent to the registrants expressing the Agency's concern. In response, the registrants submitted additional information on the chronic dog study. In December 1989, HED completed its review of this additional information and concurred with the registrants' position that the effects seen at the mid-dose were not treatment-related. HED revised the NOEL for cardiac toxicity from 0.5 to 5.0 mg/kg/day based on EKG alterations (irregular heartbeat and increased heart rate, decreased P-II values, atrial premature complexes, atrial fibrillation) and cardiac lesions (dilation of atria and atrial degeneration).[3]

2. Carcinogenicity

Atrazine has been evaluated by the HED Carcinogenicity Peer Review Committee on four separate occasions. The initial Peer Review Committee concluded that atrazine should be classified as a Group C, possible human carcinogen, based on a statistically significant increased incidence of mammary gland fibroadenomas and adenocarcinomas in female Sprague-Dawley rats.[12] Each of these increases was associated with a statistically significant dose-related trend and was outside of the historical control range. An increase in testicular interstitial cell tumors was seen at the high dose in male rats, but the Committee concluded that the tumors were not treatment-related since the incidence was within the historical control range and was seen at a dosage level that exceeded the maximum tolerated dose. The Group C classification is also supported by structural similarity to other pesticides which also induce mammary gland tumors in female rats. The Committee recommended a quantitative risk assessment based on the weight-of-evidence. The Peer Review Committee also noted that the cancer classification was considered tentative until an acceptable mouse oncogenicity study was submitted to the Agency. Once the mouse study was submitted and reviewed, the Carcinogenicity Peer Review Committee met a second time to evaluate the oncogenic

potential of atrazine. In addition to the mouse oncogenicity study, the Committee also considered a recent review of mutagenicity data available in the scientific literature and submitted to OPP. The Committee concluded that the new data presented on atrazine did not alter their conclusions that atrazine should be classified as a Group C carcinogen and that risk quantification was appropriate.[13]

In September 1988, the Scientific Advisory Panel (SAP) reviewed the available evidence and agreed with the Agency's Group C classification, but not the quantification of carcinogenic risk using a low-dose extrapolation model. The Panel concluded that the Sprague-Dawley rat is different from humans in sensitivity and that evidence of the influence of secondary factors such as the endocrine imbalance observed at high but not low doses in the rat complicates the decision about the risk to humans. The Panel recommended that quantitative risk assessment using a linear extrapolation model not be performed on atrazine.[14]

The HED Peer Review Committee met on September 29, 1988, to examine the issues raised by the SAP. The Third Peer Review Committee concurred with the SAP decision not to quantify the carcinogenic risk using a low-dose extrapolation model.[15] However, the Peer Review Committee convened for a fourth meeting to reevaluate its position. The Committee determined that there is sufficient justification for risk quantification based on: (1) malignant mammary gland tumors in the female Sprague-Dawley rat and possible decreased latency for the appearance of these tumors; and (2) the structure-activity relationship with other chemicals showing evidence of carcinogenicity.[16] The estimated Q_1^* for atrazine is 2.2×10^{-1} $(mg/kg/day)^{-1}$, based on malignant and benign mammary gland tumors in rats.[17]

B. Simazine

The HED Cancer Peer Review Committee recommended that simazine be classified as a Group C carcinogen with risk quantification based on mammary tumors in the female rat.[18] The Committee's recommendation was based on a statistically significant increased incidence of mammary gland carcinomas and combined adenomas and carcinomas when compared to controls in female Sprague-Dawley rats at the two highest doses tested. The incidence of mammary tumors had a statistically significant dose-related trend and the upper limit of the historical control was exceeded for mammary carcinomas. The weight-of-evidence also included a statistically significant increased incidence of malignant tumors in the pituitary gland; some evidence of genotoxicity; and the mammary tumor response is consistent with that seen with other triazines. The Peer Review Committee also concluded that there were inadequate hormonal data to support a hormonal mechanism theory.

The SAP reviewed the weight-of-evidence on September 28, 1989, and agreed with the Agency's Group C classification; however, the SAP recommended that the cancer risks not be quantified using a linear extrapolation model.[19] The SAP noted that certain pesticides may alter endocrine physiology in the rat and influence the incidence of mammary tumors and recommended that the Agency formulate a position on the regulation of chemicals with this mechanism. The Panel proposed that this information be incorporated in proposed revisions to the Agency's risk assessment guidelines for carcinogenicity.

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The Cancer Peer Review Committee reconvened on October 25, 1989, to evaluate the classification of simazine following the SAP meeting. The Committee concluded that it is appropriate to use a Q_1^* to quantitate the carcinogenic risk until the registrants provide data supporting a hormonal mechanism.[20] The Q_1^* for simazine, based on malignant mammary tumors in the rat, is estimated at 1.2×10^{-1} $(mg/kg/day)^{-1}$.[21]

C. Cyanazine

The HED Cancer Peer Review Committee evaluated the carcinogenic potential of cyanazine in March 1991. The Peer Review Committee concluded that cyanazine should be classified as a Group C, possible human carcinogen, and recommended quantification of risk (Q_1^*) using a low-dose extrapolation model.[22] The weight-of-evidence included statistically significant increased incidences of malignant mammary gland tumors (i.e., adenocarcinoma and carcinosarcoma) in female Sprague-Dawley rats at the two highest doses tested. These increases were associated with a statistically significant positive trend and the incidences were outside the historical control range. Additional information supporting a Group C classification include: evidence of positive genotoxic activity (mouse lymphoma gene mutation assay and unscheduled DNA synthesis in rat hepatocytes) and structural similarity to other triazine herbicides that induce mammary gland tumors.

The Q_1^* for this chemical was initially calculated based on carcinomas, adenocarcinomas, and fibrosarcomas.[21] The Q_1^* was revised after excluding animals with fibrosarcomas in the cyanazine carcinogenicity study.[23] Fibrosarcomas were excluded because they do not originate from epithelial cell tissues as do the carcinomas. As a result of a CRAVE Workgroup meeting in June 1993, the Q_1^* was recalculated excluding data from interim sacrifice animals. OPP has determined that 1.0 $(mg/kg/day)^{-1}$ is the appropriate Q_1^* for cyanazine risk characterization.[24]

IV. EXPOSURE ASSESSMENT

Occupational and residential exposure to atrazine, simazine and cyanazine varies depending on several factors including the specific crop treated, the personal protective equipment used, whether the person exposed is a grower or commercial applicator, and whether an individual is mixing, loading and/or applying the pesticide. In general, a grower is likely to be involved in all aspects of the pesticide treatment, while in commercial operations separate individuals usually mix/load and apply the pesticide. The total exposure to growers is generally lower than for commercial operators since growers usually treat fewer acres, use less pounds of active ingredient per season and are exposed for only a few days each year. HED only estimated dermal exposure to workers and residents because inhalation exposure is negligible in comparison to dermal exposure. In addition, the Special Review team determined that exposure estimates for representative sites only were sufficient for a PD 1. Therefore, no attempt has been made to evaluate additional exposure monitoring data submitted or published since the previous exposure assessments were completed.

A. Atrazine

OREB estimated exposure for mixer/loader operations and aerial, ground boom and handheld spray gun applications of atrazine at representative use sites. Exposure to aerial flaggers was also estimated. BEAD provided use data for corn, sorghum and sugarcane to represent the major atrazine use sites. Macadamia nut orchards were selected to represent handheld spray gun applications and turf uses were selected to represent home gardener uses.

OREB estimated daily and annual exposure for representative use sites using proprietary studies previously reviewed by OREB and studies in the published literature.[9-10] In terms of personal protective equipment, OREB assumed that all handlers wear long sleeve shirts, long pants and boots, but that only mixer/loaders wear chemical resistant gloves. Exposure to mixer/loaders was estimated assuming an open pour system as well as a closed loading system. For ground boom application of atrazine to corn, sorghum and sugarcane, HED distinguished exposure to applicators using an open cab from those using closed cab equipment.[11] However, it is important to note that current labels do not require closed loading nor application from closed cab tractors. Daily and annual exposure estimates, as well as key exposure parameter information, are summarized in Tables 1 and 2. Exposure estimates have been revised to reflect new use information provided by BEAD.[7-8]

B. Simazine

OREB previously estimated occupational exposure during mixing/loading, aerial and ground boom applications of simazine to corn using the same database as for the atrazine assessment. Once again, dermal exposure was estimated assuming the use of long pants and long-sleeved shirts during mixing/loading and application. It was assumed that mixer/loaders wore chemical resistant gloves in addition to the shirt and pants. The previous assessment has been expanded to include open versus closed loading systems and application from open versus closed cab tractors. In addition, HED has provided exposure estimates for workers using aerial equipment to apply simazine. The exposure estimates for closed loading systems, closed cab tractors and aerial application are based on assessments previously completed for atrazine.[9-11] Daily and annual exposure estimates, as well as exposure parameter information are contained in Tables 3 and 4.

C. Cyanazine

HED has not completed a separate exposure assessment for cyanazine, but has provided occupational exposure estimates for use on corn, the predominant use site. The exposure estimates are based on assessments completed for atrazine because both pesticides are applied in a similar fashion to field corn. Tables 5 and 6 contain daily and annual exposure estimates, as well as key use information provided by BEAD. The exposure estimates in Tables 5 and 6 were derived assuming that cyanazine is applied alone at a rate of 3 lb. a.i./acre. BEAD has indicated that cyanazine is commonly used in combination with other pesticides at an average application rate of 1.5 lb. a.i./acre.[7]

V. RISK CHARACTERIZATION

A. Margins of Exposure - Atrazine

The margins of exposure for atrazine were calculated from the following equation:

$$MOE = CF \times \frac{\text{NOEL (mg/kg/day)}}{\text{Exposure (mg/kg/day)}}$$

HED has developed a route-to-route comparison factor (CF) based on a comparison of peak blood concentration levels from oral toxicity and dermal absorption studies. These data indicate that a route-to-route comparison factor of approximately 360 is appropriate for atrazine MOE calculations.

In many instances, individuals involved in the application of atrazine are exposed for only 1 to 4 days per year, which HED considers short-term exposure. However, the cardiac effects did not occur in the 1-year dog study until 85 days following atrazine administration which constitutes an intermediate exposure scenario. Therefore, HED considers MOEs based on cardiotoxicity to be inappropriate for scenarios where individuals are exposed for only a few days per year. These scenarios are highlighted in Table 7 (see footnote 3). HED has determined that a NOEL of 5.0 mg/kg/day based on a rabbit developmental toxicity study is appropriate for acute or short-term exposure scenarios.[25] Developmental effects that occurred at 75 mg/kg/day include: increased resorptions, decreased live fetuses and decreased mean fetal body weight. Therefore, margins of exposure were derived based upon comparison of daily exposure estimates against a NOEL of 5.0 mg/kg/day (cardiotoxicity and developmental toxicity). Results in Table 7 indicate that the MOEs for workers who function as mixer/loaders and applicators are greater than 100 for all use scenarios.

B. Cancer Risk Estimates

Tables 7 through 9 contain the excess individual lifetime cancer risk estimates for occupational/residential exposure to atrazine, simazine and cyanazine. The cancer risks were calculated from the following equation:

$$\text{Extra cancer risk} = Q_1^* \times \text{LADE} \times \%\ \text{dermal absorption}$$

where Q_1^* = $0.22\ (\text{mg/kg/day})^{-1}$ for atrazine;

$0.12\ (\text{mg/kg/day})^{-1}$ for simazine;

$1.0\ (\text{mg/kg/day})^{-1}$ for cyanazine;

and $\text{LADE} = \frac{\text{exposure (mg/kg/yr)}}{365\ \text{days/yr}} \times \frac{35}{70}$ = lifetime average daily exposure.

These estimates reflect exposure values based on typical use patterns. The exposure estimates were adjusted to account for the potential dermal absorption of each herbicide as discussed below.

1. Atrazine

The dermal absorption rate was derived from a dermal absorption study in which atrazine was applied to the skin of male rats with single doses of 0.01, 0.1 or 1.0 mg/cm^2 for exposure periods of 2, 4, 10 and 24 hours.[26] After the animals were sacrificed, the application site was washed with a detergent solution and rinsed with water. The amount of atrazine actually absorbed ranged from approximately 0.1% to 4.9% across all doses and time periods, with the percentage absorbed dermally increasing with time and decreasing with increasing dose. The results indicate that absorption appears to be approaching saturation at the high dose. While only a small percentage was actually absorbed, about 9.6% to 29.0% remained on the skin following washing across all doses and time periods.

In an earlier risk assessment, HED used information on daily exposure duration, daily exposure estimates and dermal absorption to determine a specific dermal absorption rate for each use scenario.[1] However, given the variability in the duration of exposure and the amount of pesticide on the skin of a worker, HED believes it is unnecessary to calculate specific values for each exposure scenario. Rather, this assessment utilizes the dermal absorption data assuming individuals are exposed for 10 hours before washing which corresponds to the length of a typical work day. HED calculated the occupational/residential cancer risks in Table 7 for two separate scenarios: (1) using only the actual percentage absorbed (2.0%) and (2) adding actual dermal absorption and the percentage remaining on the skin following washing to obtain a potential dermal absorption value (total - 26.9%). The latter estimates assume a worst case, that all material remaining on the skin after washing will be absorbed. Data are not available to support or refute this assumption; however, HED considers the cancer risk estimates based on this assumption to be appropriate for regulatory purposes. In other words, risk management decisions should be based on the cancer risk estimates using the potential dermal absorption value.

HED estimates the excess individual lifetime cancer risks range from 10^{-6} to 10^{-2} for individuals involved in the agricultural application of atrazine (Table 7). Because growers are likely to be involved in mixing, loading and applying atrazine, it is important to consider the total risk from these operations, while different individuals are likely to mix/load and apply atrazine in a commercial operation. The occupational cancer risk estimates for atrazine are primarily dependent upon whether mixer/loaders use open versus closed loading systems and whether application occurs from open versus closed cab equipment. In addition, cancer risk estimates vary depending on the method of application. HED estimates the excess cancer risk to individuals involved in the commercial application of atrazine to lawns is 10^{-2}, while the risk to home gardeners using atrazine on lawns is estimated at 10^{-5}.

2. Simazine

As in the case of atrazine, results of a rat dermal absorption study indicate that a very small percentage of simazine is actually absorbed (< 1%).[27] Single doses of 0.1 and 0.5 mg/cm^2 were applied dermally to male rats. The animals were sacrificed at either 2, 4, 10 or 24 hours followed by a soap and water washing of the application site. The results indicate that approximately 11% to 20% of the low dose and 31% to 41% of the high dose remained on the skin after washing. A relationship between absorption and the duration of exposure was not evident. HED used the dermal absorption data for 10 hours of exposure in estimating excess individual lifetime cancer risks to workers. Table 8 contains cancer risk estimates using only the actual percentage absorbed (1%) and also for the potential rate of dermal absorption by adding actual dermal absorption and the percentage remaining on the skin following washing (32% total). Dermal absorption data are not available to indicate whether the amount remaining on the skin is actually absorbed. Cancer risk estimates based on this assumption should be considered a worst-case scenario but appropriate for regulatory purposes.

Table 8 indicates that the cancer risk to individuals involved in the application of simazine to field corn range from 10^{-6} to 10^{-2}. The occupational cancer risks are comparable to those of atrazine because both pesticides are applied using similar equipment and application rates.

3. Cyanazine

A cyanazine dermal absorption study demonstrated that less than 1% of the applied dose was actually absorbed over 8 days.[28] Cyanazine was applied to the skin of male rats as a single dose of 4.2 mg/cm^2 and animals were sacrificed at 0.5, 2, 4, 10, 24, 48, 72, 120 or 192 hours after dosing. The application site was washed at 10 hours after dosing or immediately following sacrifice of the animals at earlier time intervals (i.e., maximum exposure time was 10 hours). The maximum amount absorbed through the skin at 192 hours was approximately 0.8% of the actual dose applied. These results are consistent with those of the atrazine and simazine dermal penetration studies. However, the actual dermal absorption and amount remaining on the skin after washing (i.e., total potential dermal absorption) only reached a maximum of 2% at 24 hours, which is significantly lower than results for atrazine and simazine. HED estimated that the occupational cancer risks to individuals involved in the application of cyanazine to field corn range from 10^{-6} to 10^{-2} (Table 9). The results are comparable to those of the atrazine and simazine.

C. Strengths and Uncertainties of Risk Assessment

HED made standard assumptions in estimating occupational/residential risks including interspecies extrapolation and prorating of exposures over an individual's working lifetime (i.e., LADE). Exposure estimates were adjusted for dermal absorption (using experimentally-derived dermal absorption data in rats) because the Q_1^* for each pesticide was derived from an oral feeding study and the primary route of exposure is dermal contact. The dermal absorption data for each herbicide indicate that only a small percentage is actually

absorbed. For atrazine and simazine, a significant amount remained on the skin following washing while a small amount of cyanazine remained on the skin. HED has provided cancer risk estimates for each herbicide accounting for: (1) the actual percentage absorbed and; (2) the actual percentage absorbed plus the percentage remaining on the skin available for absorption (i.e., potential dermal absorption). The latter estimates assume the entire amount remaining on the skin is actually absorbed over time. The cancer risk estimates based on this assumption are appropriate and consistent with HED risk assessment policy. HED recommends that these estimates be used for risk management decisions.

For atrazine MOE estimates, kinetics data are available to derive route-to-route comparison factors which account for differences in systemic toxicity following dosing by two different routes. This approach more accurately characterizes the margins of exposure, but is not appropriate for cancer risk assessment purposes. Even though the kinetics data cannot be used in the same manner for estimating excess cancer risks, the data indicate that the atrazine cancer risk estimates can be characterized as upper-bound.

This occupational/residential risk assessment is not intended to comprehensively address all uses of atrazine, cyanazine and simazine. The purpose is to cover the major crops and application methods potentially resulting in the highest exposure. The exposure assessments are based on surrogate exposure data submitted to the Agency and/or published in the scientific literature. OREB has evaluated the existing exposure assessments and considers the exposure estimates for atrazine use on macadamia nuts and turf/home lawns to be weakly supported, primarily because the estimates are based on a small number of replicates.[28] An atrazine turf/lawncare exposure study was recently submitted to the Agency. OREB will conduct an exposure assessment for atrazine turf uses when the study is reviewed. HED also notes that this risk assessment is based on existing exposure assessments which were completed several years ago. No attempt has been made to investigate additional sources of data, such as the Pesticide Handlers Exposure Database, at this time. These sources of data may significantly affect current exposure and risk assessments for the triazines.

D. Summary

Daily and annual exposure estimates, as well as use related exposure data are outlined in Tables 1 through 6 for atrazine, simazine and cyanazine. The cancer risk estimates range from 10^{-6} to 10^{-2} for those individuals involved in the application of these three herbicides (Tables 7 through 9). The occupational and residential cancer risk estimates for atrazine, simazine and cyanazine are primarily dependent upon whether mixer/loaders use open versus closed loading systems and whether application occurs from open versus closed cab equipment. In addition, cancer risk estimates vary depending on the method of application. Margins of exposure for workers who function as mixer/loaders and applicators of atrazine are greater than 100 for all use scenarios (Table 7).

VI. REFERENCES:

[1]M. Copley. Atrazine; Assessment of Risk to Applicators Due to Carcinogenicity and Cardiotoxicity. Memorandum to J. Andreasen/J. Housenger (October 20, 1989).

[2]C. Lunchik. Nondietary Exposure Assessment of Simazine. Memorandum to E. Saito and H. Spencer (May 22, 1989).

[3]M. Copley. Atrazine; Reevaluation of Chronic Toxicity in the 1-year Dog Study. Memorandum to J. Andreasen/J. Housenger (December 15, 1989).

[4]H. Spencer. Atrazine Kinetic Data Use in Exposure and Risk Assessments. Memorandum to M. Beringer (March 25, 1993).

[5]R. Petrie. Use Related Exposure Data for Atrazine Exposure Assessment. Memorandum to M. Firestone (December 11, 1987).

[6]D. Szuhay. Use Data for Exposure Analysis the Application of Atrazine to Sorghum. Memorandum to M. Firestone (July 3, 1989).

[7]G. Keitt. Update of Use Data for Exposure Analysis of Triazines. Memorandum to E. Saito (March 31, 1993).

[8]R. Torla. Personal communication with M. Beringer (March 31, 1993).

[9]M. Firestone. Exposure Assessment for Policy Group. Memorandum to R. Taylor (January 6, 1988).

[10]C. Lunchick. Exposure Assessment for the Application of Atrazine to Sorghum. Memorandum to J. Andreasen (July 14, 1989).

[11]S. Knott. Non-Dietary Exposure Assessment for the Application of Atrazine Using an Open Cab Versus a Closed Cab Tractor. Memorandum to J. Andreasen (July 26, 1989).

[12]J. Hauswirth. Peer Review of Atrazine. Memorandum to R. Taylor/C. Grubbs (June 6, 1988).

[13]J. Hauswirth. Second Peer Review of Atrazine. Memorandum to R. Taylor/C. Grubbs (August 1, 1988).

[14]S. Johnson. A Set of Scientific Issues Being Considered by the Agency in Connection with the Peer Review Classification of Atrazine as a Class C Oncogen (September 14, 1988).

[15]M. Copley. Third Peer Review of Atrazine - Reevaluation Following the September 7, 1988 Scientific Advisory Panel Review. Memorandum to R. Taylor and J. Andreasen (November 22, 1988).

[16]M. Copley. Follow-up to the Third Peer Review of Atrazine. Memorandum to R. Taylor and J. Andreasen (April 27, 1989).

[17]C.J. Nelson. ATRAZINE - Updated Qualitative and Quantitative Risk Assessment from a 2-Year Chronic Oral Toxicity/Oncogenicity Study. Memorandum to M. Copley (August 23, 1989).

[18]E. Rinde. Peer Review of Simazine. Memorandum to J. Yowell (July 31, 1989).

[19]R. Jaeger. Transmittal of the Final FIFRA Scientific Advisory Panel Report on the September 28-29, 1989 Meeting. Memorandum to D. Campt (October 16, 1989).

[20]H. Spencer. Peer Review Meeting on Simazine Following SAP Review. Memorandum to J. Andreasen (May 24, 1990).

[21]B. Fisher. Cyanazine (188C), Atrazine (63) and Simazine (740) Quantitative Risk Assessment Comparisons on Malignant Mammary Gland Tumors only in Rats. Memorandum to K. Baetcke (May 13, 1991).

[22]W. Dykstra and G. Ghali. Peer Review of Cyanazine (Bladex). Memorandum to L. Rossi and J. Auerbach (July 30, 1991).

[23]B. Fisher. Cyanazine (188C), Atrazine (63) and Simazine (740) Quantitative Risk Assessment Comparisons on Malignant Mammary Gland Tumors only in Rats. Revised Comparisons as of July, 1991. Memorandum to K. Baetcke (July 8, 1991).

[24]R. Engler. Cyanazine; Quantitative Estimate of Carcinogenic Risk: Oral Slope Factor. Memorandum to J. Cogliano (June 14, 1993).

[25]M. Copley. Assessment of Acute Risk Due to Atrazine - Recommendations from the Ad Hoc Committee Regarding the Use of the Developmental Toxicity Studies. Memorandum to G. Ghali (March 25, 1993).

[26]R. Zendzian. Atrazine, Recalculation of Oncogenic Risk Utilizing Data from a Rat Dermal Absorption Study. Memorandum to M. Copley (July 18, 1988).

[27]R. Zendzian. Simazine, Review of Dermal Absorption Study. Memorandum to M. Ioannou (August 24, 1988).

[28]Q. Bui. Review of Toxicology Data of Bladex (Cyanazine). Memorandum to J. Dizikes and J. Yowell (April 23, 1986).

[29]L. Dorsey. Evaluation of Triazine Worker Exposure Assessments. Memorandum to J. Housenger (June 3, 1993).

Table 1. Atrazine - Daily Occupational/Residential Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/day)	References
Corn - Grower/Ground boom	M/L - open	0.93	1.2	112	134		1.78	5,7,9
	M/L - closed	0.015	1.2	112	134		0.029	5,7,9
	A - open	56.7	1.2			5.1	4.96	5,7,11
	A - closed	2.2	1.2			5.1	0.19	5,7,11
	M/L/A - open/open						6.74	5,7,9,11
	M/L/A - open/closed						1.97	5,7,9,11
	M/L/A - closed/open						4.99	5,7,9,11
	M/L/A - closed/closed						0.22	5,7,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	1.2	400	480		6.38	5,7,9
	M/L - closed	0.015	1.2	400	480		0.10	5,7,9
	A - open	56.7	1.2			5.3	5.15	5,7,11
	A - closed	2.2	1.2			5.3	0.20	5,7,11
	M/L/A - open/open						11.53	5,7,9,11
	M/L/A - open/closed						6.58	5,7,9,11
	M/L/A - closed/open						5.25	5,7,9,11
	M/L/A - closed/closed						0.30	5,7,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	1.2	385	462		0.099	5,7,9
	Pilot	0.58	1.2			0.8	0.008	5,7,9
	Flagger	3.2	1.2			0.8	0.044	5,7,9
Sorghum - Grower/Ground boom	M/L - open	0.93	1.0	107	107		1.42	6,8,9
	M/L - closed	0.015	1.0	107	107		0.023	6,8,9
	A - open	56.7	1.0			5.9	4.8	6,8,11
	A - closed	2.2	1.0			5.9	0.19	6,8,11
	M/L/A - open/open						6.22	6,8,9,11
	M/L/A - open/closed						1.61	6,8,9,11
	M/L/A - closed/open						4.82	6,8,9,11
	M/L/A - closed/closed						0.21	6,8,9,11

Table 1. Continued

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/day)	References
Sugarcane - Ground boom (Commercial)	M/L - open	0.93	1.0	400	400		5.31	5,9
	M/L - closed	0.015	1.0	400	400		0.086	5,9
	A - open	56.7	1.0			5.3	4.29	5,9,11
	A - closed	2.2	1.0			5.3	0.17	5,9,11
	M/L/A - open/open						9.60	5,9,11
	M/L/A - open/closed						5.48	5,9,11
	M/L/A - closed/open						4.38	5,9,11
	M/L/A - closed/closed						0.26	5,9,11
Sugarcane - Aerial	M/L - closed	0.015	1.0	440	440		0.094	5,9
	Pilot	0.58	1.0			0.9	0.007	5,9
	Flagger	3.2	1.0			0.9	0.041	5,9
Macadamia nuts - Handheld sprayer	M/L - open	5.4 mg/lb ai	2.0	5.13	10.25		0.79	5,9
	A - single/split	115 mg/lb ai	2.0	5.13	10.25		16.84	5,9
	M/L/A - single/split						17.63	5,9
Lawns - Handheld sprayer	M/L - commercial[3]	5.4 mg/lb ai	0.22 lb	30	6.6		0.51	5,9
	A - commercial	115 mg/lb ai	ai/lawn	lawns	6.6		10.8	5,9
	M/L/A - homeowner[3]	6.1 mg/hr/lb ai/A	2.1			0.6	0.11	5,9

[1]Unless otherwise noted - units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Assumes 70 kg worker.
[3]No protective gloves worn.

Table 2. Atrazine - Annual Occupational/Residential Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/yr)	References
Corn - Grower/Ground boom	M/L - open	0.93	1.2	195	234		3.11	5,7,9
	M/L - closed	0.015	1.2	195	234		0.05	5,7,9
	A - open	56.7	1.2			8.9	8.65	5,7,11
	A - closed	2.2	1.2			8.9	0.34	5,7,11
	M/L/A - open/open						11.76	5,7,9,11
	M/L/A - open/closed						3.45	5,7,9,11
	M/L/A - closed/open						8.70	5,7,9,11
	M/L/A - closed/closed						0.39	5,7,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	1.2	6000	7200		95.66	5,7,9
	M/L - closed	0.015	1.2	6000	7200		1.54	5,7,9
	A - open	56.7	1.2			80	77.76	5,7,11
	A - closed	2.2	1.2			80	3.02	5,7,11
	M/L/A - open/open						173.42	5,7,9,11
	M/L/A - open/closed						98.68	5,7,9,11
	M/L/A - closed/open						79.30	5,7,9,11
	M/L/A - closed/closed						4.56	5,7,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	1.2	5775	6930		1.49	5,7,9
	Pilot	0.58	1.2			12	0.12	5,7,9
	Flagger	3.2	1.2			12	0.66	5,7,9
Sorghum - Grower/Ground boom	M/L - open	0.93	1.0	135	135		1.79	6,8,9
	M/L - closed	0.015	1.0	135	135		0.029	6,8,9
	A - open	56.7	1.0			7.4	5.99	6,8,11
	A - closed	2.2	1.0			7.4	0.23	6,8,11
	M/L/A - open/open						7.78	6,8,9,11
	M/L/A - open/closed						2.02	6,8,9,11
	M/L/A - closed/open						6.02	6,8,9,11
	M/L/A - closed/closed						0.26	6,8,9,11

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Table 2. Continued

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/yr)	References
Sugarcane - Ground boom (Commercial)	M/L - open	0.93	1.0	6000	6000		80.0	5,9
	M/L - closed	0.015	1.0	6000	6000		1.3	5,9
	A - open	56.7	1.0			79.2	64.2	5,9,11
	A - closed	2.2	1.0			79.2	2.49	5,9,11
	M/L/A - open/open						144.2	5,9,11
	M/L/A - open/closed						82.49	5,9,11
	M/L/A - closed/open						65.5	5,9,11
	M/L/A - closed/closed						3.79	5,9,11
Sugarcane - Aerial	M/L - closed	0.015	1.0	13,200	13,200		2.8	5,9
	Pilot	0.58	1.0			27	0.22	5,9
	Flagger	3.2	1.0			27	1.23	5,9
Macadamia nuts - Handheld sprayer	M/L - open	5.4 mg/lb ai	2.0	20.5	41		3.2	5,9
	A - single applicator	115 mg/lb ai	2.0	20.5	41		67.4	5,9
	A - split application	115 mg/lb ai	2.0	10.25	20.5		33.7	5,9
	M/L/A - single app.						70.6	5,9
	M/L/A - split app.						36.9	5,9
Lawns - Handheld sprayer	M/L - commercial[3]	5.4 mg/lb ai	0.22 lb	600	132		10.2	5,9
	A - commercial	115 mg/lb ai	ai/lawn	lawns	132		216.9	5,9
	M/L/A - homeowner[3]	6.1 mg/hr/lb ai/A	2.1			1.2	0.22	5,9

[1]Unless otherwise noted - units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Assumes 70 kg worker.
[3]No protective gloves worn.

Table 3. Simazine - Daily Occupational Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/day)	References
Corn - Grower/Ground boom	M/L - open	0.93	1.1	110	121		1.61	2,5,8,9
	M/L - closed	0.015	1.1	110	121		0.026	2,5,8,9
	A - open	56.7	1.1			5.1	4.54	2,5,8,11
	A - closed	2.2	1.1			5.1	0.18	2,5,8,11
	M/L/A - open/open						6.15	2,5,8,9,11
	M/L/A - open/closed						1.79	2,5,8,9,11
	M/L/A - closed/open						4.57	2,5,8,9,11
	M/L/A - closed/closed						0.21	2,5,8,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	1.1	400	440		5.85	2,5,8,9
	M/L - closed	0.015	1.1	400	440		0.094	2,5,8,9
	A - open	56.7	1.1			5.3	4.72	2,5,8,11
	A - closed	2.2	1.1			5.3	0.18	2,5,8,11
	M/L/A - open/open						10.57	2,5,8,9,11
	M/L/A - open/closed						6.03	2,5,8,9,11
	M/L/A - closed/open						4.81	2,5,8,9,11
	M/L/A - closed/closed						0.27	2,5,8,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	1.1	385	424		0.091	2,5,8,9
	Pilot	0.58	1.1			0.8	0.007	2,5,8,9
	Flagger	3.2	1.1			0.8	0.04	2,5,8,9

[1]Units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Assumes 70 kg worker.

Table 4. Simazine - Annual Occupational Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[2] (mg/kg/yr)	References
Corn - Grower/Ground boom	M/L - open	0.93	1.1	195	215		2.86	2,5,8,9
	M/L - closed	0.015	1.1	195	215		0.046	2,5,8,9
	A - open	56.7	1.1			8.9	7.93	2,5,8,11
	A - closed	2.2	1.1			8.9	0.31	2,5,8,11
	M/L/A - open/open						10.79	2,5,8,9,11
	M/L/A - open/closed						3.17	2,5,8,9,11
	M/L/A - closed/open						7.98	2,5,8,9,11
	M/L/A - closed/closed						0.36	2,5,8,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	1.1	6000	6600		87.7	2,5,8,9
	M/L - closed	0.015	1.1	6000	6600		1.41	2,5,8,9
	A - open	56.7	1.1			80	71.3	2,5,8,11
	A - closed	2.2	1.1			80	2.77	2,5,8,11
	M/L/A - open/open						159.0	2,5,8,9,11
	M/L/A - open/closed						90.47	2,5,8,9,11
	M/L/A - closed/open						72.71	2,5,8,9,11
	M/L/A - closed/closed						4.18	2,5,8,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	1.1	5775	6353		1.36	2,5,8,9
	Pilot	0.58	1.1			12	0.11	2,5,8,9
	Flagger	3.2	1.1			12	0.60	2,5,8,9

[1]Units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Assumes 70 kg worker.

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Table 5. Cyanazine - Daily Occupational Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate[2] (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[3] (mg/kg/day)	References
Corn - Grower/Ground boom	M/L - open	0.93	3.0	112	336		4.46	5,7,9
	M/L - closed	0.015	3.0	112	336		0.072	5,7,9
	A - open	56.7	3.0			5.1	12.39	5,7,11
	A - closed	2.2	3.0			5.1	0.48	5,7,11
	M/L/A - open/open						16.85	5,7,9,11
	M/L/A - open/closed						4.94	5,7,9,11
	M/L/A - closed/open						12.46	5,7,9,11
	M/L/A - closed/closed						0.55	5,7,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	3.0	400	1200		15.94	5,7,9
	M/L - closed	0.015	3.0	400	1200		0.26	5,7,9
	A - open	56.7	3.0			5.3	12.88	5,7,11
	A - closed	2.2	3.0			5.3	0.50	5,7,11
	M/L/A - open/open						28.82	5,7,9,11
	M/L/A - open/closed						16.44	5,7,9,11
	M/L/A - closed/open						13.14	5,7,9,11
	M/L/A - closed/closed						0.76	5,7,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	3.0	385	1155		0.25	5,7,9
	Pilot	0.58	3.0			0.8	0.020	5,7,9
	Flagger	3.2	3.0			0.8	0.11	5,7,9

[1]Units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Routinely used in combination with other pesticides at 1.5 lb ai per acre.
[3]Assumes 70 kg worker.

Table 6. Cyanazine - Annual Occupational Exposure

Crop/Application Method	Tasks	Unit Exposure[1]	Rate[2] (lb ai/acre)	Acres Treated	Pounds Handled	Duration (hours)	Exposure[3] (mg/kg/yr)	References
Corn - Grower/Ground boom	M/L - open	0.93	3.0	195	585		7.77	5,7,9
	M/L - closed	0.015	3.0	195	585		0.13	5,7,9
	A - open	56.7	3.0			8.9	21.63	5,7,11
	A - closed	2.2	3.0			8.9	0.84	5,7,11
	M/L/A - open/open						29.40	5,7,9,11
	M/L/A - open/closed						8.61	5,7,9,11
	M/L/A - closed/open						21.76	5,7,9,11
	M/L/A - closed/closed						0.97	5,7,9,11
Corn - Commercial/Ground boom	M/L - open	0.93	3.0	6000	18,000		239.1	5,7,9
	M/L - closed	0.015	3.0	6000	18,000		3.86	5,7,9
	A - open	56.7	3.0			80	194.4	5,7,11
	A - closed	2.2	3.0			80	7.54	5,7,11
	M/L/A - open/open						433.5	5,7,9,11
	M/L/A - open/closed						246.64	5,7,9,11
	M/L/A - closed/open						198.26	5,7,9,11
	M/L/A - closed/closed						11.40	5,7,9,11
Corn - Commercial/Aerial	M/L - closed	0.015	3.0	5775	17,325		3.71	5,7,9
	Pilot	0.58	3.0			12	0.30	5,7,9
	Flagger	3.2	3.0			12	1.65	5,7,9

[1]Units are mg/lb ai handled for mixer/loaders and mg/hr/lb ai/acre for ground applicators, pilots and flaggers.
[2]Routinely used in combination with other pesticides at 1.5 lb ai per acre.
[3]Assumes 70 kg worker.

Table 7. Atrazine - Cancer Risk and Cardiotoxicity MOEs

Crop/Application Method	Tasks	Daily Exposure	Annual Exposure	LADE	Cancer Risk[1]	Cancer Risk[2]	Margins of Exposure
Corn - Grower/Ground boom[3]	M/L - open	1.78	3.11	4.3×10^{-3}	1.9×10^{-5}	**2.5×10^{-4}**	1010
	M/L - closed	0.029	0.05	6.8×10^{-6}	3.0×10^{-7}	**4.0×10^{-6}**	62,070
	A - open	4.96	8.65	1.2×10^{-2}	5.3×10^{-5}	**7.1×10^{-4}**	365
	A - closed	0.19	0.34	4.7×10^{-4}	2.1×10^{-6}	**2.8×10^{-5}**	9475
	M/L/A - open/open	6.74	11.76	1.6×10^{-2}	7.0×10^{-5}	**9.5×10^{-4}**	265
	M/L/A - open/closed	1.97	3.45	4.7×10^{-3}	2.1×10^{-5}	**2.8×10^{-4}**	915
	M/L/A - closed/open	4.99	8.70	1.2×10^{-2}	5.3×10^{-5}	**7.1×10^{-4}**	360
	M/L/A - closed/closed	0.22	0.39	5.3×10^{-4}	2.3×10^{-6}	**3.1×10^{-5}**	8180
Corn - Commercial/Ground boom	M/L - open	6.38	95.66	1.3×10^{-1}	5.7×10^{-4}	**7.7×10^{-3}**	280
	M/L - closed	0.10	1.54	2.1×10^{-3}	9.2×10^{-6}	**1.2×10^{-4}**	18,000
	A - open	5.15	77.76	1.1×10^{-1}	4.8×10^{-4}	**6.5×10^{-3}**	350
	A - closed	0.20	3.02	4.1×10^{-3}	1.8×10^{-5}	**2.4×10^{-4}**	9000
	M/L/A - open/open	11.53	173.42	2.4×10^{-1}	1.1×10^{-3}	**1.4×10^{-2}**	155
	M/L/A - open/closed	6.58	98.68	1.4×10^{-1}	6.2×10^{-4}	**8.3×10^{-3}**	275
	M/L/A - closed/open	5.25	79.30	1.1×10^{-1}	4.8×10^{-4}	**6.5×10^{-3}**	345
	M/L/A - closed/closed	0.30	4.56	6.2×10^{-3}	2.7×10^{-5}	**3.7×10^{-4}**	6000
Corn - Commercial/Aerial	M/L - closed	0.099	1.49	2.0×10^{-3}	8.8×10^{-6}	**1.2×10^{-4}**	18,180
	Pilot	0.008	0.12	1.6×10^{-4}	7.0×10^{-7}	**9.5×10^{-6}**	225,000
	Flagger	0.044	0.66	9.0×10^{-4}	4.0×10^{-6}	**5.3×10^{-5}**	40,910
Sorghum - Grower/Ground boom[3]	M/L - open	1.42	1.79	2.5×10^{-3}	1.1×10^{-5}	**1.5×10^{-4}**	1270
	M/L - closed	0.023	0.029	4.0×10^{-5}	1.8×10^{-7}	**2.4×10^{-6}**	78,260
	A - open	4.8	5.99	8.2×10^{-3}	3.6×10^{-5}	**4.9×10^{-4}**	375
	A - closed	0.19	0.23	3.2×10^{-4}	1.4×10^{-6}	**1.9×10^{-5}**	9475
	M/L/A - open/open	6.22	7.78	1.1×10^{-2}	4.8×10^{-5}	**6.5×10^{-4}**	290
	M/L/A - open/closed	1.61	2.02	2.8×10^{-3}	1.2×10^{-5}	**1.7×10^{-4}**	1120
	M/L/A - closed/open	4.82	6.02	8.2×10^{-3}	3.6×10^{-5}	**4.9×10^{-4}**	375
	M/L/A - closed/closed	0.21	0.26	3.6×10^{-4}	1.6×10^{-6}	**2.1×10^{-5}**	8570

Table 7. Continued

Crop/Application Method	Tasks	Daily Exposure	Annual Exposure	LADE	Cancer Risk[1]	Cancer Risk[2]	Margins of Exposure
Sugarcane - Ground boom (Commercial)	M/L - open	5.31	80.0	1.1×10^{-1}	4.8×10^{-4}	6.5×10^{-3}	340
	M/L - closed	0.086	1.3	1.8×10^{-3}	7.9×10^{-6}	1.1×10^{-4}	20,930
	A - open	4.29	64.2	8.8×10^{-2}	3.9×10^{-4}	5.2×10^{-3}	420
	A - closed	0.17	2.49	3.4×10^{-3}	1.5×10^{-5}	2.0×10^{-4}	10,590
	M/L/A - open/open	9.60	144.2	2.0×10^{-1}	8.8×10^{-4}	1.2×10^{-2}	190
	M/L/A - open/closed	5.48	82.49	1.1×10^{-1}	4.8×10^{-4}	6.5×10^{-3}	330
	M/L/A - closed/open	4.38	65.5	9.0×10^{-2}	4.0×10^{-4}	5.3×10^{-3}	410
	M/L/A - closed/closed	0.26	3.79	5.2×10^{-3}	2.3×10^{-5}	3.1×10^{-4}	6925
Sugarcane - Aerial	M/L - closed	0.094	2.8	3.8×10^{-3}	1.7×10^{-5}	2.2×10^{-4}	19,150
	Pilot	0.007	0.22	3.0×10^{-4}	1.3×10^{-6}	1.8×10^{-5}	257,145
	Flagger	0.041	1.23	1.7×10^{-3}	7.5×10^{-6}	1.0×10^{-4}	43,900
Macadamia nuts - Handheld sprayer[3]	M/L - open	0.79	3.2	4.4×10^{-3}	1.9×10^{-5}	2.6×10^{-4}	2280
	A - single applicator	16.84	67.4	9.2×10^{-2}	4.0×10^{-4}	5.4×10^{-3}	107
	A - split application	16.84	33.7	4.6×10^{-2}	2.0×10^{-4}	2.7×10^{-3}	107
	M/L/A - single app.	17.63	70.6	9.7×10^{-2}	4.3×10^{-4}	5.7×10^{-3}	102
	M/L/A - split app.	17.63	36.9	5.1×10^{-2}	2.2×10^{-4}	3.0×10^{-3}	102
Lawns - Handheld sprayer	M/L - commercial	0.51	10.2	1.4×10^{-2}	6.2×10^{-5}	8.3×10^{-4}	3530
	A - commercial	10.8	216.9	3.0×10^{-1}	1.3×10^{-3}	1.8×10^{-2}	165
	M/L/A - homeowner[3]	0.11	0.22	3.0×10^{-4}	1.3×10^{-6}	1.8×10^{-5}	16,365

[1]Actual dermal absorption = 2.0%.
[2]Potential dermal absorption = 26.9%
[3]Exposure is only 1 to 4 days per year.

Table 8. Simazine - Occupational Cancer Risk Estimates[1]

Crop/Application Method	Tasks	Daily Exposure	Annual Exposure	LADE	Cancer Risk[1]	Cancer Risk[2]
Corn - Grower/Ground boom	M/L - open	1.61	2.86	3.9×10^{-3}	4.7×10^{-6}	1.5×10^{-4}
	M/L - closed	0.026	0.046	6.3×10^{-5}	7.6×10^{-8}	2.4×10^{-6}
	A - open	4.54	7.93	1.1×10^{-2}	1.3×10^{-5}	4.2×10^{-4}
	A - closed	0.18	0.31	4.2×10^{-4}	5.0×10^{-7}	1.6×10^{-5}
	M/L/A - open/open	6.15	10.79	1.5×10^{-2}	1.8×10^{-5}	5.8×10^{-4}
	M/L/A - open/closed	1.79	3.17	4.3×10^{-3}	5.2×10^{-6}	1.7×10^{-4}
	M/L/A - closed/open	4.57	7.98	1.1×10^{-2}	1.3×10^{-5}	4.2×10^{-4}
	M/L/A - closed/closed	0.21	0.36	4.9×10^{-4}	5.9×10^{-7}	1.9×10^{-5}
Corn - Commercial/Ground boom	M/L - open	5.85	87.7	1.2×10^{-1}	1.4×10^{-4}	4.6×10^{-3}
	M/L - closed	0.094	1.41	1.9×10^{-3}	2.3×10^{-6}	7.3×10^{-5}
	A - open	4.72	71.3	9.8×10^{-2}	1.2×10^{-4}	3.8×10^{-3}
	A - closed	0.18	2.77	3.8×10^{-3}	4.6×10^{-6}	1.5×10^{-4}
	M/L/A - open/open	10.57	159.0	2.2×10^{-1}	2.6×10^{-4}	8.4×10^{-3}
	M/L/A - open/closed	6.03	90.47	1.2×10^{-1}	1.4×10^{-4}	4.6×10^{-3}
	M/L/A - closed/open	4.81	72.71	1.0×10^{-1}	1.2×10^{-4}	3.8×10^{-3}
	M/L/A - closed/closed	0.27	4.18	5.7×10^{-3}	6.8×10^{-6}	2.2×10^{-4}
Corn - Commercial/Aerial	M/L - closed	0.091	1.36	1.9×10^{-3}	2.3×10^{-6}	7.3×10^{-5}
	Pilot	0.007	0.11	1.5×10^{-4}	1.8×10^{-7}	5.8×10^{-6}
	Flagger	0.04	0.60	8.2×10^{-4}	9.8×10^{-7}	3.1×10^{-5}

[1]Actual dermal absorption = 1%.
[2]Potential dermal absorption = 32%.

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Table 9. Cyanazine - Occupational Cancer Risk Estimates[1]

Crop/Application Method	Tasks	Daily Exposure	Annual Exposure	LADE	Cancer Risk[1]	Cancer Risk[2]
Corn - Grower/Ground boom	M/L - open	4.46	7.77	1.1×10^{-2}	1.1×10^{-4}	2.2×10^{-4}
	M/L - closed	0.072	0.13	1.8×10^{-4}	1.8×10^{-6}	3.6×10^{-6}
	A - open	12.39	21.63	3.0×10^{-2}	3.0×10^{-4}	6.0×10^{-4}
	A - closed	0.48	0.84	1.2×10^{-3}	1.2×10^{-5}	2.4×10^{-5}
	M/L/A - open/open	16.85	29.40	4.0×10^{-2}	4.0×10^{-4}	8.0×10^{-4}
	M/L/A - open/closed	4.94	8.61	1.2×10^{-2}	1.2×10^{-4}	2.4×10^{-4}
	M/L/A - closed/open	12.46	21.76	3.0×10^{-2}	3.0×10^{-4}	6.0×10^{-4}
	M/L/A - closed/closed	0.55	0.97	1.3×10^{-3}	1.3×10^{-5}	2.6×10^{-5}
Corn - Commercial/Ground boom	M/L - open	15.94	239.1	3.3×10^{-1}	3.3×10^{-3}	6.6×10^{-3}
	M/L - closed	0.26	3.86	5.3×10^{-3}	5.3×10^{-5}	1.1×10^{-4}
	A - open	12.88	194.4	2.7×10^{-1}	2.7×10^{-3}	5.4×10^{-3}
	A - closed	0.50	7.54	1.0×10^{-2}	1.0×10^{-4}	2.0×10^{-4}
	M/L/A - open/open	28.82	433.50	5.9×10^{-1}	5.9×10^{-3}	1.2×10^{-2}
	M/L/A - open/closed	16.44	246.64	3.4×10^{-1}	3.4×10^{-3}	6.8×10^{-3}
	M/L/A - closed/open	13.14	198.26	2.7×10^{-1}	2.7×10^{-3}	5.4×10^{-3}
	M/L/A - closed/closed	0.76	11.40	1.6×10^{-2}	1.6×10^{-4}	3.2×10^{-4}
Corn - Commercial/Aerial	M/L - closed	0.25	3.71	5.1×10^{-3}	5.1×10^{-5}	1.0×10^{-4}
	Pilot	0.02	0.30	4.1×10^{-4}	4.1×10^{-6}	8.2×10^{-6}
	Flagger	0.11	1.65	2.3×10^{-3}	2.3×10^{-5}	4.6×10^{-5}

[1]Actual dermal absorption = 1% (rounded from 0.8%).
[2]Potential dermal absorption = 2%.

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