Pesticide Toxicity Thresholds: Derivation and Use in CEAP Cropland Modeling

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Introduction

The USDA Conservation Effects Assessment Project (CEAP) has been designed to quantify the environmental effects of conservation practices that are applied on agricultural lands. CEAP toxicity risk analyses use pesticide loss output from the physical process model Agricultural Policy/Environmental eXtender (APEX) (Williams et al. 2006; Williams et al. 2008; Gassman et al. 2009 and 2010). This paper provides detailed instructional methodology of toxicity value determination in the CEAP Toxicity Database used for CEAP risk analyses, which will enable the reader to continue to expand the CEAP toxicity database as more pesticides are added to the CEAP Pesticide Properties Database (Plotkin, Bagdon and Hesketh, 2020). An earlier paper *Pesticide Risk Indicators Used in CEAP Cropland Modeling* (Plotkin, et al., 2011), provided a general description of toxicity risk analyses in CEAP.

CEAP uses APEX modeling to evaluate conservation practice effects on mass losses for pesticides in runoff, subsurface lateral return flow beyond the edge of the field, and leaching below the bottom of the soil profile. Management practices that reduce the potential for loss of pesticides from farm fields consist of a combination of Integrated Pesticide Management (IPM) techniques and water erosion control practices. IPM consists of management strategies for prevention, avoidance, monitoring, and suppression (PAMS) of pest populations. Water erosion

control practices mitigate the loss of pesticides from farm fields by reducing surface water runoff and sediment loss, both of which carry pesticide residue from the farm field to the surrounding environment. Impacts from conservation practices are evaluated by determining the ratio of annual mass losses and associated mean annual pesticide concentrations to two environmental toxicity thresholds:

Aquatic Ecosystem Toxicity Threshold which can include:

- Sensitive fish species' chronic NOEL;
- Sensitive aquatic invertebrate species' chronic NOEL;
- Phytoplankton EC50; and
- Aquatic vascular plants.

Human Drinking Water Lifetime Toxicity Threshold which can include:

- EPA Office of Water Maximum Contaminant Level (MCL);
- EPA Office of Water Health Advisory (HA);
- Calculated Health Advisory (HA*); and
- Calculated Chronic Human Carcinogenic Level (CHCL).

Three "edge-of-field" pesticide risk indicators are used to assess the effects of conservation practices regarding:

- Surface water pesticide risk for aquatic ecosystems;
- Surface water pesticide risk for human drinking water; and
- Groundwater pesticide risk for human drinking water.

Resulting risk units on a per acre basis indicate that total pesticide risk contributes to total acres represented by each CEAP sample point. Risk can also be summed for an entire hydrologic unit based on the risk contributed from all cropped land within the watershed.

Pesticide toxicity risk in surface water includes soluble pesticide residues in runoff and subsurface water flow pathways that eventually return to the surface. Groundwater toxicity risk is based on solubilized pesticide in water leaching below the soil profile. Pesticide risk for aquatic ecosystems is based on chronic toxicities for fish and invertebrates, and acute toxicities for nonvascular and vascular aquatic plants. The lowest toxicity value within each biological group is used in determining the toxicity value for the aquatic ecosystem. The human drinking water toxicity threshold is determined from the lifetime chronic toxicity.

Potential environmental risk from pesticides sorbed to soil organic carbon or charged soil particles in sediment runoff losses is not directly evaluated in CEAP. These pesticide losses associated with waterborne sediment can contribute to the exposure for some aquatic organisms especially pond and stream benthos. However, trends in sediment-sorbed pesticide reduction are qualitatively evaluated in that conservation practices that decrease surface water runoff will decrease pesticide risk from both soluble and sediment-sorbed pesticide losses.

Methods

Evaluating Toxicity Risk in CEAP

Evaluating toxicity risk requires determining the ratio of the mean annual pesticide concentration to toxicity threshold, termed the Aquatic Risk Factor (ARF) (Equation 1). When this ratio is less than one, there is a low potential for adverse toxicity impact.

The ARF increases in direct proportion to runoff and leachate pesticide concentration. The value is unitless in that the pesticide concentration and the threshold concentration are in the same units (micrograms/liter also termed parts per billion) and therefore units cancel. APEX runs are based upon more than 50 years of historical weather data from hundreds of weather stations in the contiguous U.S. Generally, the weather data set used for APEX simulation of a data point (farm) is based on the farm's proximity to the closest weather collection station.

(Equation 1)

$$ARF(i) = \frac{\text{(Mean Annual Pesticide Concentration)}}{\text{(Toxicity Threshold)}} < 1$$

Low Potential for Adverse Impact

Determining Pesticide Concentration in Runoff and Leachate

APEX simulations require daily maximum and minimum air temperatures in addition to the 50+ years of historical daily precipitation data. Solar radiation, wind speed and direction are estimated using the APEX climate generator that uses data collected over a period of years at each site Soluble pesticide runoff includes both overland runoff and subsurface lateral return flow. To compensate for very low or very high individual field water volume losses that can skew pesticide concentration levels, mean annual water runoff is calculated based on the sum of edge of field runoff and subsurface lateral flow for all sample points in each USGS classified 8-digit watershed. Pesticide concentrations for each field are calculated by dividing the mean annual soluble mass loss for each field for the simulation period, by the average edge of field flow for each point in an 8-digit watershed. These mean edge of field flows were used to approximate flow of a local 1st order stream that is fed solely by agricultural fields in the 8-digit watershed. An analogous procedure was used to determine pesticide concentrations in leachate. This was achieved by dividing pesticide mass losses in deep percolation by the mean 8-digit annual water flux that percolates below the soil profile.

Toxicity Thresholds

Pesticide concentrations are divided by toxicity thresholds to obtain the ARFs. CEAP toxicity risk analyses use human drinking water and ecosystem toxicity thresholds taken from the CEAP Human Drinking Water and Aquatic Ecosystem Toxicity Database most recently updated in January 2021 (Plotkin, Bagdon and Hesketh, January 2021). The database contains 83 fields of toxicity data and associated information including over 50 fields containing comprehensive

documentation, toxicity derivation methodology and metadata. The most recent version of this database and the CEAP Pesticide Properties Database can both be found at: nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/?cid=nrcs143_014165.

Human Drinking Water Lifetime Toxicity Thresholds

Lifetime human drinking water toxicity thresholds including Maximum Contaminant Levels (MCL) and Health Advisories (HA) have been established by the EPA Office of Water (OW) for only 110 pesticides in the CEAP toxicity database (Table 1). EPA OW determines MCLs and HAs from empirically derived chronic Reference Doses (cRfD) and cancer probability slopes (Q*) based upon chronic mammalian studies. cRfD is expressed as mg/kg body weight/day. It is defined by EPA OW (2018) as:

"An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."

Cancer slope or Q* is determined by performing a chronic mammalian cancer study and is presented as the cancer risk in units mg/kg body weight/day. Q* may be used to calculate the cancer risk at any probability level desired.

The remaining approximately 900 pesticide toxicity thresholds in the CEAP toxicity database have been calculated or estimated by CEAP personnel based on EPA OW methodology (USEPA OW, 2018). Frequency of human drinking water toxicity threshold "types" in the CEAP toxicity database are determined using the following hierarchy and compiled in Table 1. EPA OW pesticide cancer classifications used in calculating toxicity thresholds are presented in Table 2.

1. Maximum Contaminant Level (MCL) is the EPA "gold standard" for pesticide toxicity thresholds that integrate all toxicity considerations including, but not limited to, cRfD for the noncarcinogenic toxicity component and cancer slope, Q*. EPA OW targets the one in one million probability level of contracting cancer in a lifetime to determine the MCL for human carcinogens and probable cancer-causing pesticides (EPA, 2020). However, EPA OW considers cost, analytical detection limits and other factors in determining an MCL consistent with the probability level of contracting cancer between one in one million and one in one hundred thousand (EPA OW Personal Communication, 1994). Also, it is notable that there are a few carcinogenic pesticides in the 2018 EPA OW Drinking Water Standards and Health Advisories table that have an assigned MCL at the one in ten thousand probability level. Additionally, in rare instances, the noncarcinogenic pesticide toxicity is more toxic than the carcinogenic component. In these rare cases, the noncarcinogenic toxicity component cRfD is considered by EPA in lowering the MCL to a level that that covers noncarcinogenic and carcinogenic toxicity. Ideally, all registered pesticides should have an established EPA OW MCL, but in fact there are only about 50 pesticides with an MCL in the CEAP toxicity database (Table 1).

2. EPA OW has established a Health Advisory (HA) for 60 pesticides currently in the CEAP toxicity database (Table 1). HAs are mostly determined for pesticides that are known not to be

carcinogenic (cancer class “E”) or do not have a cancer classification (cancer class “D”). Pesticides with a “C” classification (possible human carcinogen) are assigned an HA by employing an additional safety factor of 10. EPA OW calculates HA using Equation 2 (EPA, 1990). The equation uses a Relative Source Contribution (RSC) which EPA OW assumes to be 20% expressed as 0.2 for drinking water. EPA OW assumes body weight to be 70 kg for an adult and water consumption to be 2 liters per day.

(Equation 2)

Lifetime HA in ppb = ((cRfD in mg/kg bw/day) X (70 kg adult) X (RSC=0.2) / (2 L water/day)) X 1,000 µg/mg)

This reduces to:

Lifetime HA in ppb = (cRfD in mg/kg bw/day) X 7,000

EPA OW recommends that pesticides classified as “Suggestive evidence of carcinogenic potential” (previously known as Possible Human Carcinogen or Cancer Class “C”), have an HA determined by dividing by an additional safety factor of 10 as shown in Equation 3.

(Equation 3)

Lifetime HA in ppb for Cancer Class “C” pesticides = cRfD X 7,000 / (Safety Factor=10)

In recent years, EPA publications have indicated that in rare cases for carcinogenic pesticides the cancer-causing toxicity is less toxic than the noncarcinogenic toxicity component. In these cases, the noncarcinogenic toxicity threshold, cRfD, is sufficient to account carcinogenic potential without factoring in any additional safety margin (EPA OPP Pesticide Fact Sheets and the Federal Register). This should be considered when CEAP personnel calculate a Health Advisory (HA*) for a pesticide that does not have an EPA OW determined HA.

3. EPA OW has not determined an HA for the majority of registered pesticides. However, usually EPA has established a cRfD. If a cRfD is available, by employing EPA’s cancer class rating, a Health Advisory can be calculated which is deemed HA*. This calculation is performed using EPA OW methodology discussed above in Item 2, with the appropriate safety factor for the cancer class. Accordingly, HA*s have been calculated for pesticides in the CEAP toxicity database that are considered noncarcinogenic pesticides.

4. In some instances, no cRfD has been established by EPA. However, many of these pesticides have had chronic human toxicity evaluated by the environmental agency in Canada, Europe and/or Australia. These foreign agencies determine the Acceptable Daily Intake (ADI) in units mg/kg bw/day that is comparable to the cRfD. Sometimes these agencies have also evaluated cancer class when EPA has not (Cancer Class “D”). These cancer classifications can then be employed when calculating a human drinking water threshold. ADI can be used interchangeably with the cRfD in calculating an HA*.

5. Pesticides that are not human carcinogens and do not have an established cRfD or ADI can sometimes still be evaluated for toxicity by employing the *No Observable Adverse Effect Level* (NOAEL) or *Lowest Observable Adverse Effect Level* (LOAEL) from chronic or subchronic mammalian toxicity studies in accordance with EPA methodology. EPA estimates a cRfD from the chronic NOAEL or LOAEL in animal chronic or subchronic toxicity studies by dividing by an Uncertainty Factor (UF) as shown in Equation 4 (EPA, 1993).

(Equation 4)

cRfD = (Chronic or Subchronic NOAEL or LOAEL)/UF

Where:

Chronic NOAEL	UF = 100
Chronic LOAEL	UF = 1,000
Subchronic NOAEL	UF = 1,000
Subchronic LOAEL	UF = 10,000

6. Some pesticides that have been categorized as a Human Carcinogen or Possible Human Carcinogen (Cancer Class "A" or "B") do not have an MCL but may have a cancer slope (Q*) that has been empirically derived.

For these pesticides, the Chronic Human Carcinogenic Level (CHCL) (a term coined at NRCS by Plotkin, Bagdon and Hesketh, 1998) has been calculated using the cancer slope generated from chronic mammalian testing at the one in one hundred thousand probability of contracting cancer over a lifetime. The CHCL is assumed to approximate the MCL for pesticides that are known, likely, or possible human carcinogens (Cancer Classes "A", "B"). As previously addressed, EPA OW determines an MCL for a carcinogenic pesticide to be between the one in one million and one in one hundred thousand probability level and in a few cases EPA makes an exception using the one in ten thousand probability level (EPA OW, 2018). The drinking water CHCL at the one in one hundred thousand probability (or at any probability desired) is calculated for carcinogenic pesticides using Equation 5 (USEPA, 1990). Additionally, to account for the rare case when the noncarcinogenic toxicity is more toxic than the carcinogenic component, the CHCL is determined by calculating a Health Advisory from the cRfD or ADI if the cRfD is not available. This complies with EPA's method of adjusting the MCL to account for pesticide noncarcinogenic toxicity that is greater than the carcinogenic component (Zavaleta, 1992). This occurs for three of the 82 pesticides that have a CHCL in the CEAP toxicity database.

(Equation 5)

Concentration in drinking water (ppb)= ((Risk Probability such as 0.00001) X (70 kg adult)) / ((Q* X 2 liters/day) X (1,000 µg/mg))

7. Finally, many biological pesticides have not been tested to the extent that a cRfD or even a NOAEL has been established. However, if EPA has sufficient evidence that a pesticide is very safe, they report in a Biological Pesticide Fact Sheet that the pesticide is "Practically Nontoxic". In order to quantitatively represent this safety level, a greater than (>) 10,000 ppb toxicity level is used in WIN-PST Humtox and the CEAP toxicity database. Ten thousand ppb was selected given that several "safe" biologicals have been found to have a human drinking water toxicity in this order.

Table 1: Human Drinking Water Toxicity Thresholds in the CEAP Toxicity Database as of October 26, 2020

Standard Type	**Occurrences in Database**
Maximum Contaminant Level (MCL)[1]	50
Health Advisory (HA)[1]	60
Health Advisory estimated (HA*)[2]	800
Chronic Human Carcinogenic Level[3]	75
Guideline (WHO Human Health Guideline)[4]	1
Total	**986**

[1]USEPA Office of Water (2018)
[2]HA* represent NRCS estimated Health Advisory
[3]One in one hundred thousand probability of contracting cancer over a human lifetime
[4]Chlorotoluron, WHO Guidelines for Drinking Water, 1998

Table 2: Human Drinking Water Cancer Class in the CEAP Toxicity Database

Cancer Descriptor*

USEPA Current Cancer Class Descriptors: Carcinogenic to humans

- Likely to be carcinogenic to humans
- Likely to be carcinogenic above a specified dose, but not likely to be carcinogenic below that dose because a key event in tumor formation does not occur below that dose
- Suggestive evidence of carcinogenic potential
- Inadequate information to assess carcinogenic potential
- Not likely to be carcinogenic to humans

USEPA Former Cancer Class Descriptors and still used by some EPA divisions:

- A Human carcinogen
- B1 Probable human carcinogen from limited human evidence
- B2 Probable human carcinogen from sufficient evidence in animals and inadequate or no evidence in humans
- C Possible human carcinogen
- D Not classifiable as to human carcinogenicity
- E Evidence of non-carcinogenicity for humans

[*] 2018 Edition of the Drinking Water Standards and Health Advisories (USEPA OW, 2018) or Chemicals Evaluated for Carcinogenic Potential Annual Cancer Report 2019 (USEPA OPP, 2019).

Human Drinking Water Toxicity Data: Internet Searches

Internet searches for quantitative and qualitative human toxicity data begin with EPA websites. When information is not forthcoming from an EPA source, other websites from Europe Australia, Canada, WHO and from other Google searches can be useful. The following schema may be used in locating publications that provide toxicity information.

1. The EPA Office of Water, Drinking Water Standards and Health Advisories publication is sporadically published and includes Maximum Contaminant Levels (MCLs) and Health Advisories (HAs) for about 170 pesticides. Not all of these pesticides are included in the CEAP Pesticide Properties Database or CEAP toxicity database. The most recent publication is the *2018 Edition of the Drinking Water Standards and Health Advisories* (EPA OW, 2018). EPA OW only determines an MCL or HA for pesticides that have been detected in groundwater. Unfortunately, most pesticides are not monitored. The EPA OW document can be found at: https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

2. Cancer classification for most registered pesticides can be found in the annually published EPA Office of Pesticides, *Chemicals Evaluated for Carcinogenic Potential Annual Cancer Report.* The most recent report was published in 2019 (EPA OPP, 2019). The EPA OPP document can be found at: https://apublica.org/wp-content/uploads/2020/05/chemicals-evaluated.pdf

3. Go to the EPA OPP **Chemical Search** website and input the pesticide name. Click on the most recent regulatory document or Pesticide Fact Sheet. Website: https://iaspub.epa.gov/apex/pesticides/f?p=CHEMICALSEARCH:1:16017976404423:

4. EPA publishes human pesticide toxicity information including for newly registered pesticides in the Federal Register. This document will often provide a cRfD if one has been established. The cancer class and sometimes the cancer slope for a carcinogenic pesticide is usually provided here as well. The best way to find these documents is by performing a Google search inputting the **pesticide name** (e.g., **Atrazine**) and the words **Federal Register**. Otherwise you can go directly to the Federal Register website: www.federalregister.gov

5. There are instances where a cRfD may not be presented in the Federal Register publication on a specific pesticide, but citations may be provided in the Federal Register report that provide information located elsewhere, such as on the **Government Regulations** website. This website is worth exploring for pesticide information even if it is not addressed in a Federal Register document. Go to the Government Regulations Website and search under the pesticide name or, if known, a specific docket number at: www.regulations.gov

6. The EPA Integrated Risk Information System (IRIS) has pesticide toxicity information for mostly older pesticides. IRIS is infrequently updated including the addition of newly registered pesticides. IRIS can be found at: https://www.epa.gov/iris

7. When all of the above fail to provide a cRfD, a Google search may sometimes locate a publication that provides a cRfD, ADI or at least a NOAEL.

8. If an cRfD cannot be found, the ADI determined by environmental agencies in Europe, Canada, Australia or the World Health Organization (WHO) may provide an ADI. The ADI is comparable to the cRfD. The European ADI is published in the University of Hertfordshire PPDB: Pesticide Properties Database and BPDB: Bio-Pesticides Database. Their websites for synthetic pesticides and biological pesticides are respectively:

University of Hertfordshire PPDB: Pesticide Properties Database
https://sitem.herts.ac.uk/aeru/ppdb/en/atoz.htm

University of Hertfordshire BPDB: Bio-Pesticides Database
https://sitem.herts.ac.uk/aery/bpdb/atoz.htm

Health Canada can sometimes provide toxicity that is unavailable from EPA. Their website is:
www.canada.ca

Australian and WHO reports for a specific pesticide can be found by performing Google searches.

9. Occasionally, a Material Safety Data Sheet (MSDS) from a pesticide manufacturer may provide a cRfD and/or other toxicity information.

10. A cRfD and associated Health Advisory (HA*) may be calculated using the methods shown above in this document if a chronic NOAEL from a mammalian study has be done.

11. Finally, EPA reports on biological pesticides often do not have a quantitative toxicity value but may provide qualitative information about a pesticide, such as, 'the pesticide is not expected to be hazardous to humans including babies and children'. In these instances, the HA* is assumed to be > 10,000 ppb. These documents can be found either by performing a Google search or going to the EPA Chemical Search website:
https://iaspub.epa.gov/apex/pesticides/f?p=CHEMICALSEARCH:1:16017976404423

Aquatic Ecosystem Toxicity Thresholds

Characterization of aquatic ecosystems should include as many aquatic animal and plant groups as possible. Ecosystem protection requires determining a toxicity threshold for the most sensitive biological group for each pesticide (weakest link in the food web). There are four biological groups that are most commonly tested for toxicity to pesticides and used by EPA in their aquatic ecosystem risk assessments including: sensitive fish species, aquatic invertebrates, aquatic vascular plants and aquatic nonvascular plants (phytoplankton). The ecological interaction of these four biological groups are vital for a healthy aquatic ecosystem. If one of these groups are seriously harmed, the ecosystem may collapse. Therefore, the CEAP Human Drinking Water and

Aquatic Ecosystem Toxicity Database uses the most sensitive threshold from the following biological groups:

- Fish chronic threshold -- No Observable Effect Concentration (NOEL) for the most sensitive fish species tested;
- Aquatic invertebrate chronic threshold -- No Observable Effect Concentration (NOEL) for the most sensitive aquatic invertebrate species tested;
- Aquatic vascular plant acute toxicity thresholds – Effective Concentration that is lethal to 50% of the population (EC50) for the most sensitive species tested;
- Aquatic nonvascular plant (phytoplankton) acute toxicity threshold – Effective Concentration that is lethal to 50% of the population (EC50) (most sensitive species tested).

Unfortunately, due to a paucity of available data, other aquatic biological groups are not considered in the aquatic wildlife criteria evaluation such as amphibians (e.g., frogs and salamanders) and aquatic reptiles (e.g., snakes and turtles) even though they are vital links in the aquatic ecosystem.

Of the over one thousand pesticides in the CEAP toxicity database, about 95% have an ecosystem toxicity value (Table 3). Toxicity preference for each of the four biological groups was given to the EPA Office of Pesticide Programs (OPP) Aquatic Life Benchmarks (EPA OPP, 2014). EPA Benchmarks are analogous to a water quality standard for each plant or animal group. EPA OPP recommends that their benchmarks be used as a guide by state environmental agencies in establishing aquatic biological criteria. Additionally, EPA OPP has suggested that at some future point the toxicities for these four biological groups may suffice in performing an ecological risk assessment (EPA OPP. 2014)

When performing an ecological risk assessment in a Pesticide Fact Sheet, EPA Office of Prevention, Pesticides, and Toxic Substances (OPPTS) uses chronic toxicity data for fish and invertebrates and acute toxicity data for aquatic vascular plants and nonvascular aquatic plants. EPA OPP toxicity benchmarks were created for just such a purpose. As depicted in Table 3, aquatic plants and animals have a decreasing toxicity data availability order with fish species having been tested the most. The number of pesticides tested for each biological group by descending order for both benchmark and non-benchmark toxicity studies are: Fish studies > Aquatic invertebrate studies > Nonvascular aquatic plants (phytoplankton) studies > Aquatic vascular plants studies.

Non-Benchmark pesticide toxicity for each biological group was taken from various sources. The lowest toxicity value available (most toxic) was used for each biological group to populate the CEAP aquatic ecosystem toxicity database. Source preference was given to the EPA OPP Environmental Effects Database (also known as ECOTOX) even if the toxicity value presented was not the lowest available elsewhere. This is the primary data source used by EPA OPP in determining Benchmark values and used in EPA OPPTS risk assessments. ECOTOX was last updated February 9, 2018 but is no longer being supported by EPA (USEPA OPP, February 9,

2018). Also, as of 2018, the latest version of ECOTOX on the IPM Centers website was February 2017.

The Aquatic Ecosystem toxicity value used for CEAP risk analyses is the most toxic threshold among the four biological groups. For example, if fish NOEL = 2.0 ppb, aquatic invertebrate NOEL = 3.0 ppb, aquatic vascular plant EC50 = 1.0 ppb and phytoplankton EC50 = 0.5 ppb, then the Aquatic Ecosystem toxicity would be 0.5 ppb based on the phytoplankton EC50. In the majority of instances, toxicity values are not available for all four biological groups. If less than the four biological group toxicity values are available, the lowest toxicity value (most toxic) is selected from the values available and used as a proxy to represent the aquatic ecosystem toxicity value.

Table 3: CEAP Ecosystem Toxicity Threshold Input Type

Threshold Type	**Occurrences in Database**
Fish Benchmark NOEL[1]	170
Invertebrate Benchmark NOEL[1]	168
Nonvascular Aquatic Plants Benchmark EC50[1]	173
Vascular Aquatic Plants Benchmark EC50[1]	135
Benchmarks for All 4 Biological Groups[1]	90
Non-Benchmarks:	
Fish NOEL[2]	990
Invertebrate NOEL[2]	591
Nonvascular Aquatic Plants EC50[2]	370
Vascular Aquatic Plants EC50[2]	278

[1]EPA Office of Pesticide Programs (2014)
[2]CEAP Human Drinking Water and Aquatic Ecosystem Toxicity Database (October, 2020)

Fish Chronic Toxicity

Fish are at the top of the food web. However, there is a hierarchy to fish species with some adult fish species eating the larval fish and fry of other species and larger species of fish consuming smaller species. Fish are important to keeping a balance in the food web by consuming invertebrates and in some cases algae and aquatic vegetation. The eggs and young of fish are protected by the roots of floating aquatic vegetation such as duckweed (*Lemna gibba*) and the stems of emergent aquatic vegetation.

The most sensitive fish species (fresh or salt water) available for each pesticide (often the freshwater warm-water bluegill sunfish or cold-water rainbow trout) is an important indicator organism of the health of the aquatic environment. The No Observed Effect Level (NOEL), also called in the toxicological literature the No Observed Effect Concentration (NOEC), is the chronic toxicity endpoint that is used by EPA OPP. NOELs are determined empirically in laboratory toxicity studies. Approximately one-third of the non-Benchmark fish NOELs in the CEAP toxicity database were determined this way. The majority were taken from ECOTOX

(EPA OPP, 2012 -2018) if available or from the EPA Office of Prevention, Pesticides, and Toxic Substances (OPPTS) Pesticide Fact Sheets. About 10 to 20% of the fish NOELS were obtained from the toxicological literature including journal articles, websites and books. NOELs for nontoxic biological pesticides described by EPA as practically nontoxic were assumed to be > 500 ppb. This is the toxicity range used in WIN-PST for practically nontoxic pesticides.

The remaining two-thirds of the fish toxicities in the CEAP toxicity database had only acute fish toxicity available, usually at the 96-hour LC50 level (lethal concentration that kills 50% of a species' population). NOELs were extrapolated from these LC50s using the fish Log10 NOEL - Log10 96-hour LC50 linear regression developed by Plotkin (July, 2010, unpublished) following methodology similar to that of Barnthouse et al. (1990), and as shown in Equation 6. The regression equation was derived from matched pairs (N=57) of the same species from empirically determined fish 96-hour LC50s and NOELs from ECOTOX (EPA OPP, 2010).

(Equation 6)

Log10 (Fish NOEL) = 0.889 X Log10 (LC50) – 0.779; (N=57, R^2 = 0.81)

Aquatic Invertebrate Chronic Toxicity

Aquatic invertebrates are vital to the ecosystem as a food source to fish. If their population is decimated by pesticides, it will harm animals higher in the food web including fish. This is in addition to the risk imparted directly to fish. Invertebrates such as Daphnia and rotifers help keep the bacteria and unicellular algae population in check. They effectively prevent unicellular algal blooms from becoming too prolific and thereby slow eutrophication.

The lowest chronic aquatic invertebrate NOEL (most toxic) available was selected for each pesticide as another important indicator of ecosystem health. Preference was given to the ECOTOX database. Most sensitive invertebrate chronic NOELs in the toxicological literature are for the water flea crustaceans *Daphnia magna* and *Daphnia pulex*. About 40% of the invertebrate toxicity values in the CEAP toxicity database are experimentally determined NOELs. When a chronic toxicity value was unavailable, the most toxic acute value (usually the 48-hour EC50) available was used to estimate the chronic NOEL using the Log10 (48-hour EC50) -Log10 (chronic NOEL) linear regression (Equation 7) developed by Plotkin (2010, unpublished) following methodology similar to that of Barnthouse et al. (1990). Toxicity values for matched species pairs used for the regression analysis were taken from ECOTOX (EPA OPP, 2010).

(Equation 7)

Log10 (Invertebrate NOEL) = 0.928 X (invertebrate Log10 (EC50)) – 0.981; (N= 100, R^2 = 0.86)

EC50 is the pesticide concentration that has an "effect" on 50% of the species' population. Daphnids are so small that it is easier to determine an "effect" such as a lack of movement than to know when an individual is dead. Most of the chronic and acute aquatic invertebrate toxicity

values in the CEAP aquatic toxicity database were taken from ECOTOX (EPA OPP, February 9, 2018).

Aquatic Plant Acute Toxicity

Generally, acute toxicity testing duration for aquatic plants ranges from 1 to 14 days. The aquatic plant toxicity endpoint is usually an EC50 (concentration of pesticide that has an effect such as chlorophyll or biomass reduction or that kills 50 percent of a species' population). Most of the toxicity values for aquatic plants in the CEAP toxicity database were taken from ECOTOX (EPA OPP, February 9, 2018).

Aquatic vascular plants and algae are at the base of the food web in ponds and streams and are known as primary producers. Herbicides are often found particularly harmful to aquatic plants as indicated by the highly toxic EC50 values that are usually determined for a 7- to 14-day period. If this base of the food web is eliminated or severely damaged, the pond or stream ecosystem will collapse and organisms that are higher in the food web such as fish and invertebrates will be tremendously impacted or completely eliminated regardless of how toxic a pesticide or group of pesticides directly impact a species. Aquatic vascular plants also provide vital habitat and protection for fish, invertebrates, salamanders, frogs, turtles and other aquatic species in ponds and lakes. Vascular plants are necessary for these animals to avoid predation of their young. Most of the vascular plant toxicity thresholds in the CEAP toxicity database are from the surface floating aquatic macrophyte duckweed (*Lemna gibba*). These plants only survive in shallow areas of ponds and lakes.

Free floating nonvascular plants (phytoplankton) are the primary producers of biomass in deeper areas of a pond or lake and can also be important in shallower areas. Daphnia feed primarily on unicellular phytoplankton. Significant toxic impact to the unicellular phytoplankton community will directly impair the Daphnia population and other invertebrates that in turn provide a food source to fish, amphibians, etc. (Wetzel, 2001). Some algae attach to substrates such as rocks (epilithic algae) and macrophytes (epiphytic algae). However, nearly all nonvascular plant toxicity values in the CEAP toxicity database pertain to free floating unicellular phytoplanktonic species, especially green algae and diatom species. A few toxicity values pertain to filamentous blue-green algae, so-called nuisance algae, which are not beneficial to an aquatic ecosystem and usually only proliferate in highly disturbed aquatic ecosystems such as highly polluted eutrophic ponds and lakes (Wetzel, 2001).

Toxicity from Pesticides Sorbed to Sediment

Toxicity risk from pesticides sorbed to organic carbon or charged soil particles in sediment runoff losses is not evaluated in CEAP. Sorbed pesticides are of particular concern to benthic organisms in ponds, lakes and streams. IPM and NRCS conservation practices that decrease runoff are likely to decrease risk from both soluble and sorbed pesticide losses. Additionally, the concentration of soluble pesticide runoff and percolation is dependent upon the sorptive proclivity of a pesticide to soil particles estimated by the organic carbon sorption coefficient, Koc.

Aquatic Ecosystem Toxicity Data: Internet Searches

1. The EPA OPP Environmental Effects Database (also referred to as ECOTOX) is the best and most comprehensive resource for acute and chronic pesticide toxicity values to aquatic and to many terrestrial species. It is limited to EPA sanctioned toxicity studies so does not include many toxicity studies found in the toxicological literature. The toxicity values from this database are used by EPA OPP to do their risk assessments that are part of the Pesticide Fact Sheets. As of early 2018, the database was discontinued. However, the ECOTOX database management may resume in the future. The database may be downloaded from any of the IPM Centers websites at: www.ecotox.ipmcenters.org

2. The EPA OPP Chemical Search website is another good resource for pesticide toxicity information. Type in the name of the pesticide to investigate and click on the most recent regulatory documents or Pesticide Fact Sheet. During the period of January 2017 until January 2021, these pesticide reports were not available for newly registered pesticides. Likely, these reports which are legally required to be in the public domain will become available in the future. Go to: https://iaspub.epa.gov/apex/pesticides/f?p=CHEMICALSEARCH:1:16017976404423

3. The University of Hertfordshire PPDB: Pesticide Properties Database and BPDB: Bio-Pesticides Database are excellent resources for fish and aquatic invertebrate acute and chronic toxicity and for acute toxicity to aquatic vascular plants and nonvascular aquatic plants (phytoplankton). Go to:

University of Hertfordshire PPDB: Pesticide Properties Database
https://sitem.herts.ac.uk/aeru/ppdb/en/atoz.htm

and

University of Hertfordshire BPDB: Bio-Pesticides Database
https://sitem.herts.ac.uk/aery/bpdb/atoz.htm

4. The Pesticide Action Network (PAN) Pesticide Database is another useful resource for ecological toxicity data. Their new website is: www.panna.org

5. The Health Canada Pest Management Regulatory Agency website is often useful for toxicity values event when EPA has very little information available. The Health Canada website is: www.canada.ca

6. EXTOXNET Fact Sheets and the updated National Pesticide Information Center Fact Sheets, respectively from Oregon State University provide useful toxicity information on their websites: www.extoxnet.orst.edu and www.npic.orst.edu

7. Other sources of toxicity data can best be found by performing Google searches.

Evaluating Risk: Aggregating Aquatic Risk Factor

Aquatic risk analyses are determined by generating combined losses in runoff or leaching toward the groundwater by specific pesticides or groups of pesticides through aggregation of Aquatic Risk Factors (ARFs). This technique does not consider synergistic or antagonistic toxicological effects from more than one pesticide being leached or in runoff and does not account for differences in pesticide dose response. However, ARF risk aggregation is a simple technique that assumes additive toxicological impact and can be used to investigate total risk at a single sample point, a watershed or an entire river basin (Equation 1). Aquatic ecosystem and human drinking water risk indicators can be used in a multitude of risk analyses. Some of these uses that are employed in CEAP include:

1. Toxicity risk from each pesticide applied at a sample point.

2. Risk summation for all pesticides applied at a single sample point.

3. Risk summation for each pesticide that is applied to many sample points in a watershed.

4. Risk mitigation when one or more NRCS Conservation Practices are applied.

5. Optimizing risk mitigation with selected combinations of NRCS Conservation Practices and Integrated Pest Management (IPM) Techniques.

6. Determining where pesticide use does not require mitigation.

7. Calculating the mean annual risk per sample point applied for each pesticide.

8. Quantifying the relative risk of each pesticide applied in a watershed.

9. Determining the percentage of an agricultural field where the selected risk indicator is > 1.

10. Assessing risk units from combined pesticide runoff (includes subsurface flow that reaches the surface and combines with surface flow).

11. Assessing risk units from pesticides leaching below the soil profile.

In CEAP I and 2011 – 2013 Special CEAP Studies, statistical analyses were performed based on USDA National Resource Inventory (NRI) statistical analyses to determine the weighted representation for each sample point (farm field). These acreage weights were applied to the pesticide ARFs to determine impact from each pesticide applied to a farm field in a watershed using Equation 8. This weighting plays an important role in risk aggregation because the risk at each point is carried over to all acres represented by that point. Aggregated risks are well suited for comparing the effects of model runs that employ conservation practices (CEAP survey baseline condition) such as IPM practices with simulations that have had conservation practices removed (no-practice scenarios). Conservation practices tend to have the effect of decreasing

pesticide-contaminated water in runoff at the edge of the field (e.g., conservation tillage and structural practices) or leaching pesticide (e.g., increased soil organic matter that binds the pesticide to soil particles), filtering pesticides residues with buffers, or decreasing the need for pesticide application with IPM techniques such as crop rotations and pesticide banding. Risk evaluation can also be used to show the effectiveness of IPM techniques (e.g., reduced pesticide applications based on pest pressure).

(Equation 8)

Total Risk from a Pesticide in a Watershed = [(Pesticide 1 ARF) X (Field 1 Weighted Expansion Factor 1)] + [(Pesticide 1 ARF) X (Field 2 Weighted Factor2)] + …

Aggregation of risk from all pesticides applied to a field can be achieved by combining the average annual ARFs contributed from each pesticide (Equation 9).

(Equation 9)

$$\textbf{Pesticide Risk Aggregation on a Sample Point} = \sum_{i=1}^{n} \textbf{Pesticide(i) ARF}$$

Example of the Risk Process: Sample Point Risk Aggregation

An illustration of the process of developing ARFs and aggregating them is presented below for a hypothetical river basin in Tables 4 and 5. Table 4 provides APEX modeled pesticide loss examples from runoff and deep percolation flows used to determine pesticide concentrations. Each pesticide concentration in combined runoff flow, including subsurface return flow, is meant to approximate a local first order stream by calculating the average of the annual combined surface runoff and subsurface return flow for all sample points in the HUC 8 watershed where the sample point is located. Percolation flows are determined from the average of deep percolation water from all the sample points in the HUC 8 watershed. The pesticides acetochlor, atrazine and glyphosate isopropalamine salt were applied on an example sample point. Application rates of acetochlor (840 grams per hectare) and glyphosate (544 grams per hectare) were greater than the application rate of 332 grams per hectare of atrazine. However, due the greater water solubility and soil mobility (lower Koc) of atrazine, its 3.1 grams per hectare runoff was closer to the runoff of 5.09 grams per hectare acetochlor than would be expected by their respective application rates. Glyphosate isopropalamine salt soluble runoff was significantly less at 0.099 grams per hectare than that of atrazine or acetochlor even though it is extremely soluble in water due to its lower soil mobility (extremely high Koc). Atrazine's high mobility also resulted in a 2.6 micrograms per liter concentration in deep percolation compared to only 0.01 micrograms per liter of acetochlor and 0.0 micrograms per liter of glyphosate isopropalamine salt.

Table 4: Pesticide Losses and Associated Dilution on a Hypothetical Sample Point

Pesticide	Appl. Rate (g/ha)	Runoff (g/ha)	Dilution Flow (cm)	Average Annual Runoff Conc. (µg/L)	Percolate (g/ha)	Dilution Flow (cm)	Average Annual Percolate Conc. (µg/L)
Acetochlor	840	3.562	7.0	5.09	0.002	3.2	0.01
Atrazine	332	2.153	7.0	3.1	0.82	3.2	2.6
Glyphosate Isopropylamine Salt	544	0.099	7.0	0.14	0.00	3.2	0.00

Table 5 shows the drinking water and ecosystem risks contributed from each pesticide by dividing pesticide concentration by toxicity threshold. Acetochlor being slightly less toxic to humans but more toxic to the aquatic ecosystem compared to atrazine, had a 0.46 runoff human drinking water risk and an aquatic ecosystem risk of 3.56, while atrazine's runoff risks to humans and the aquatic system were 1.0 and 3.1, respectively. This shows the importance of considering toxicity risk to more than just humans. Glyphosate isopropalamine salt had very low risk values of 0.0 for both human and aquatic ecosystem. Since most glyphosate losses are tied up in sediment sorption and on terrestrial plant surfaces, one might expect that the greatest toxic impact from this pesticide in the aquatic environment would be to organisms that reside in the sediment (benthos). There is no officially approved EPA methodology to evaluate toxicity risk from pesticides sorbed to sediment. Consequently, this component of pesticide risk analysis is not performed in CEAP.

Total risk units from the sample point shown in Table 5 were determined by aggregation of risk or ARF units. Total human drinking water runoff risk for this sample point was 1.46, while the aggregated ecosystem runoff risk was 6.66, indicating that there is greater potential risk to the aquatic ecosystem than to human drinking water. However, both of these aggregations exceeded 1, indicating that there may be potential toxicity risk to both humans and particularly to the aquatic ecosystem at the local 1st order stream level.

Table 5: Pesticide Toxicity and Risk to Humans and the Aquatic Ecosystem

Pesticide	Pesticide Runoff Conc. (µg/L)	Human Tox. (µg/L)	Runoff Human Risk Units	Percola-tion Human Risk Units	Pesticide Percola-tion Conc. (µg/L)	Ecosystem Tox. (µg/L)	Runoff Ecosystem Risk Units	Percola-tion Ecosystem Risk Units
Acetochlor	5.09	11	0.46	0.0	0.01	1.43	3.56	0.01
Atrazine	3.1	3	1.0	0.9	2.6	1.0	3.1	2.6
Glyphosate Isopropyl-amine Salt	0.14	700	0.0	0.0	0.0	1.68	0.0	0.0
Total Risk			**1.46**	**0.9**			**6.66**	**2.7**

Risk Process Example – Collective Risk from Each Pesticide in the Upper Mississippi River Basin

CEAP risk analyses may also include collective risk to an entire river basin. As mentioned above, there are numerous ways to express total risk from each pesticide to a watershed or river basin. This type of aggregation is an effective way to compare the relative risks being contributed by each pesticide being applied to farm fields in a region such as the CEAP Upper Mississippi River Basin (UMRB) study (Kellogg et al. 2010). The relative risk to the aquatic ecosystem for the entire river basin is determined by considering the percent of cropped acres with an ARF risk indicator greater than one as presented in Table 6. In the UMRB example, atrazine was shown to contribute to ecosystem toxicity risk in 28% of the cropped acres while 6% of the acres were impacted by acetochlor. All the other pesticides combined that were applied in the basin contributed to the total ecosystem toxicity risk by < 13% acres. However, risk analysis in one HUC 16 watershed within the UMRB where other pesticides were applied such as the highly toxic pesticides phostebupirim and chlorpyrifos, show ecosystem risk to a substantial percentage of the acres within that watershed. Use of the ARF enables consideration of pesticide applications, movement on the landscape through runoff and percolation as well as toxicity impacts to humans and the aquatic ecosystem. This method enables a better understanding of toxic impacts and the benefits of mitigation via conservation practices.

Table 6: Relative Average Annual Runoff Ecosystem Risks from Pesticides Applied in the Upper Mississippi River Basin

Pesticide	Pesticide Type	% of Cropped Acres with ARF >1
Atrazine	Herbicide	28
Acetochlor	Herbicide	6
Phostebupirim	Insecticide	4
Metolachlor	Herbicide	2
Chlorpyrifos	Insecticide	2
Tefluthrin	Insecticide	<1
Carbofuran	Insecticide	<1
S-Metolachlor	Herbicide	<1
Flufenacet	Herbicide	<1
All other pesticides		<2

Table 7: CEAP Human Drinking Water and Aquatic Ecosystem Pesticide Toxicity Database Column Headings Definitions

Toxicity Database Column Header	Definition
Pesticide	Pesticide name
CAS#	Chemical abstracts service number
AICODE	EPA chemical code number
Aquatic Ecosystem Toxicity (ppb)	Most toxic concentration among the fish, aquatic invertebrates, aquatic vascular plants and phytoplankton
Human Drinking Water Toxicity (ppb)	Human drinking water toxicity parameter
Human Tox Type	Toxicity parameter: MCL, HA, HA*(calculated HA) or CHCL
Benchmark Fish GTLT	EPA OPP benchmark fish toxicity concentration ">" or "<" mathematical indicator
Benchmark Fish NOEL ppb	EPA OPP benchmark fish chronic "No Effect Level" toxicity concentration
Benchmark Invert GTLT	EPA OPP benchmark aquatic invertebrate toxicity concentration ">" or "<" mathematical indicator
Benchmark Invert NOEL ppb	EPA OPP benchmark aquatic invertebrate chronic "No Effect Level" toxicity concentration
Benchmark Phytoplankton GTLT	EPA OPP benchmark phytoplankton toxicity concentration ">" or "<" mathematical indicator
Benchmark Phytoplankton EC50 ppb	EPA OPP benchmark phytoplankton acute "Effective Concentration" that damages 50% of a species' population toxicity concentration
Benchmark Aquatic Vascular Plants GTLT	EPA OPP benchmark aquatic vascular plant toxicity concentration ">" or "<" mathematical indicator
Benchmark Aquatic Vascular Plants EC50 ppb	EPA OPP benchmark aquatic vascular plant acute "Effective Concentration" that damages 50% of the species' population
Fish GTLT	EPA OPP benchmark fish toxicity concentration ">" or "<" mathematical indicator
Fish NOEL (ppb)	Non-benchmark fish chronic "No Effect Level" toxicity concentration
Aquatic Invertebrates GTLT	Non-benchmark aquatic invertebrate toxicity concentration ">" or "<" mathematical indicator
Aquatic Invertebrates NOEL (ppb)	Non-benchmark aquatic invertebrate chronic "No Effect Level" toxicity concentration

Table 7: CEAP Human Drinking Water and Aquatic Ecosystem Pesticide Toxicity Database Column Headings Definitions (continued)

Toxicity Database Column Header	Definition
Phytoplankton GTLT	Non-benchmark phytoplankton toxicity concentration ">" or "<" mathematical indicator
Phytoplankton EC50 (ppb)	Non-benchmark phytoplankton acute "Effective Concentration" that damages 50% of a species' population toxicity concentration
Aquatic Vascular Plants GTLT	Non-benchmark aquatic vascular plant toxicity concentration ">" or "<" mathematical indicator
Aquatic Vascular Plants EC50 (ppb)	Non-benchmark aquatic vascular plant acute "Effective Concentration" that damages 50% of the species' population
Fish NOEL min	Benchmark fish NOEL if available, otherwise non-benchmark NOEL
Invert NOEL min	Benchmark aquatic invertebrate NOEL if available, otherwise non-benchmark NOEL
Phytoplankton EC50 min	Benchmark phytoplankton EC50L if available, otherwise non-benchmark EC50
Aq vasc EC50 min	Benchmark aquatic vascular plant EC50 if available, otherwise non-benchmark EC50
Aquatic Ecosystem Toxicity (ppb)	Most toxic concentration among the fish, aquatic invertebrates, aquatic vascular plants and phytoplankton
EPA OPP Benchmark Reference	Reference citation for EPA OPP benchmarks
Pesticide: Human Drinking Water	Pesticide name
Human Cancer Class	EPA OW cancer class if available, otherwise EPA OPP cancer class
Human Q*(cancer slope)	Pesticide cancer slope for calculating CHCL
Human EPA OPP cRfD (mg/Kg/day)	EPA OPP human consumption pesticide toxicity chronic reference dose
Human WHO cRfD (mg/Kg/day)	World Health Organization human consumption pesticide toxicity chronic reference dose
Human EPA OW cRfD (mg/Kg/day)	EPA OW human drinking water pesticide toxicity chronic reference dose
Human EPA cRfD (mg/Kg/day)	EPA human consumption pesticide toxicity chronic reference dose
Human Study Time	Mammalian toxicity study time

Table 7: CEAP Human Drinking Water and Aquatic Ecosystem Pesticide Toxicity Database Column Headings Definitions (continued)

Toxicity Database Column Header	Definition
Human Comment1	Human comment
Human Comment2	Secondary human comment
Human Toxicity (ppb)	Human drinking water toxicity parameter
Human Toxicity Type	Human drinking water toxicity type (MCL, HA, HA* or CHCL)
Human Q* Reference	Human cancer slope reference citation
Human Toxicity Source	Reference citation for human toxicity and/or cancer class
Pesticide: Fish	Pesticide name
Fish Species Common Name	Fish species nonscientific common name
Fish Taxonomic Name	Fish species scientific name
Fish Age Documentation	Fish age of test subjects
Fish A.I. %	% pesticide active ingredient in product used in toxicity test
Fish Calculation (ppb)	Fish toxicity calculation (e.g., LC50 to NOEL)
Fish Study Time	Fish study time period
Fish GTLT	Fish toxicity > or < mathematical indicator
Fish NOEL (ppb)	Fish toxicity chronic "No Effect Level"
Fish Source	Fish reference citation
Pesticide: Aquatic Invertebrates	Pesticide name
Aquatic Invertebrates Common Name	Aquatic invertebrate species nonscientific common name
Aquatic Invertebrates Taxonomic	Aquatic invertebrate species scientific name
Aquatic Invertebrates Age	Aquatic invertebrate age of test subjects
Aquatic Invertebrates A.I. %	% pesticide active ingredient in product used in toxicity test
Aquatic Invertebrates Study Time	Aquatic invertebrate study time period
Aquatic Invertebrates Toxicity Type	Aquatic invertebrate toxicity type (e.g., 48-hour EC50)
Aquatic Invertebrates Acute Toxicity GTLT	Aquatic invertebrate acute toxicity > or < mathematical indicator
Aquatic Invertebrates Acute Toxicity	Aquatic invertebrate acute EC50 toxicity concentration

Table 7: CEAP Human Drinking Water and Aquatic Ecosystem Pesticide Toxicity Database Column Headings Definitions (continued)

Toxicity Database Column Header	Definition
Aquatic Invertebrates NOEL Calculation: Log10(EC50) to Log10(NOEL)	Aquatic invertebrate toxicity calculation (e.g., 48-h EC50 to NOEL)
Aquatic Invertebrates NOEL GTLT	Aquatic invertebrate chronic NOEL toxicity > or < mathematical indicator
Aquatic Invertebrates NOEL (ppb)	Aquatic invertebrate toxicity chronic "No Effect Level"
Aquatic Invertebrates Toxicity Source	Aquatic invertebrate reference citation
Pesticide: Phytoplankton	Pesticide name
Phytoplankton A.I. %	% pesticide active ingredient in product used in toxicity test
Phytoplankton Common Name	Phytoplankton species nonscientific common name
Phytoplankton Taxonomic	Phytoplankton species scientific name
Phytoplankton Study Time	Phytoplankton study time period
Phytoplankton GTLT	Phytoplankton acute toxicity > or < mathematical indicator
Phytoplankton EC50 (ppb)	Phytoplankton acute EC50 toxicity concentration
Phytoplankton Source	Phytoplankton reference citation
Pesticide: Aquatic Vascular Plants	Pesticide name
Aquatic Vascular Plants Common Name	Aquatic vascular plant species nonscientific common name
Aquatic Vascular Plants Taxonomic	Aquatic vascular plant species scientific name
Aquatic Vascular Plants A.I. %	% pesticide active ingredient in product used in toxicity test
Aquatic Vascular Plants Study Time	Aquatic vascular plant study time period
Aquatic Vascular Plants GTLT	Aquatic vascular plant acute toxicity > or < mathematical indicator
Aquatic Vascular Plants EC50 (ppb)	Aquatic vascular plant acute EC50 toxicity concentration
Aquatic Vascular Plants Source	Aquatic vascular plant reference citation

Summary

Methodology has been described for determining pesticide toxicity to human drinking water and the aquatic ecosystem in the CEAP Human Drinking Water and Aquatic Ecosystem Toxicity Database.

1. This paper is designed to be a companion document to the current version of the CEAP Human Drinking Water and Aquatic Ecosystem Pesticide Toxicity Database last updated October, 2020.

2. The database is being used for toxicity risk analyses of modeled survey information collected in the CEAP Farmer Surveys by USDA NASS.

3. Nearly 1,000 human drinking water chronic toxicity values populate the database.

4. Human drinking water toxicity types in the database include EPA OW Maximum Contaminant Level (MCL) and Health Advisories (HA) as well as NRCS\UMass Extension calculated Health Advisories (HA*) and Chronic Human Carcinogenic Level (CHCL) determined using EPA OW methodology.

5. The human non-carcinogenic toxicity component is derived from the EPA chronic Reference Dose (cRfD), European, Canadian or Australian chronic Acceptable Daily Intake (ADI) that is comparable to the cRfD, or from the No Observable Adverse Effect Level (NOAEL) or Lowest Observable Adverse Effect Level (LOAEL) determined from chronic or subchronic mammalian toxicity studies.

6. The aquatic ecosystem component of the CEAP toxicity database consists of the fish and aquatic invertebrate chronic No Observable Effect Level (NOEL) and acute aquatic vascular and nonvascular plant Effective Concentration that impacts 50% of a species' population. There are aquatic ecosystem toxicity values applicable to over 1,000 pesticides in the CEAP database.

7. Fish and aquatic invertebrate NOELs were collected from aquatic toxicological literature or calculated using Log-Log linear regressions from Plotkin (2010a and 2010b), respectively.

8. Aquatic plant acute toxicity values were collected primarily from the EPA OPP ECOTOX database and a relatively small number of toxicity values from the aquatic toxicological literature.

9. The most sensitive biological group for each pesticide is used to evaluate aquatic ecosystem toxicity risk.

10. Over 50 fields in the CEAP toxicity database contain documentation, calculation methods, assumptions, and metadata.

11. Methodology was provided that shows how toxicity values are used to analyze toxicological risk in CEAP modeling of agricultural use of pesticides in the United States.

12. The Aquatic Risk Factor (ARF) is determined by calculating the ratio (annual pesticide runoff or percolate concentration) / (toxicity threshold). A value that exceeds 1 indicates potential risk. Total risk from all pesticides applied to a field can be estimated by summing the ARFs from the average annual pesticide losses. Risk units for a larger area such as a watershed can be determined by aggregating the ARFs for the average annual concentrations for each specific pesticide over all fields and accounting for expansion weighting. For example, toxicity risk aggregation from atrazine applied to many fields within a watershed.

References

Barnthouse, L. W., G. W. Suter and A. E. Rosen. 1990. Risk of Toxic Contaminants to Exploited Fish Populations: Influence of Life History, Data Uncertainty and Exploitation Intensity. Environ. Tox. Chem. 9:297-311.

EPA. November, 2020. Risk Assessment Regional Screening Levels (RSLs) – User's Guide. U.S. Environmental Protection Agency. https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#mcls

EPA Office of Pesticide Programs. 2014. Office of Pesticide Programs' Aquatic Life Benchmarks. USEPA Office Pesticide Programs. Washington D.C.

EPA Office of Pesticide Programs. February 9, 2018. Environmental Effects Database (EEDB). USEPA Environmental Fate and Effects Division. Office of Pesticide Programs. Washington D.C.

EPA Office of Pesticide Programs. March 15, 1993. Reference Dose (RfD): Description and Use in Health Risk Assessments Background Document 1A March 15, 1993. USEPA Office of Pesticide Programs. Washington D.C.

EPA Office of Drinking Water Health Advisories. April, 1990. Drinking Water Health Advisory: Pesticides. USEPA Office of Drinking Water Health Advisories. Lewis Publishers.

EPA Office of Water. March, 2018. Edition of the Drinking Water Standards and Health Advisories. USEPA Office of Water. Washington D.C.

EPA Office of Pesticide Programs. 2019. Chemicals Evaluated for Carcinogenic Potential. USEPA Office of Pesticide Programs. Washington D.C.

Gassman, P.W., J.R. Williams, S. Wang, A. Saleh, E. Osei, L. Hauck, C. Izaurralde, and J. Flowers. 2009. The Agricultural Policy Environmental Extender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses. Technical Report 09-TR 49. CARD, Iowa State Univ., Ames, IA.

Gassman, P.W., J.R. Williams, S. Wang, A. Saleh, E. Osei, L. Hauck, C. Izaurralde, and J. Flowers. 2010. The Agricultural Policy Environmental Extender (APEX) Model: An Emerging Tool for Landscape and Watershed Environmental Analyses. *Trans. of the ASABE*. Vol. 53(3): 711-740.

Kellogg, R.L. et al. Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin. USDA NRCS Publication. 2010.

Plotkin, S. July, 2010. Fish Acute 96-h LC50 to Chronic NOEL Log-Log Linear Regression Equation. Unpublished. USDA NRCS. Amherst, MA.

Plotkin, S. July, 2010. Aquatic Invertebrate Acute 48-h EC50 to Chronic NOEL Linear Regression Equation. Unpublished. USDA NRCS. Amherst, MA.

Plotkin, S., J. K. Bagdon and E.S. Hesketh. October, 2020. CEAP Human Drinking Water and Aquatic Ecosystem Toxicity Database. USDA NRCS. Amherst, MA.

Plotkin, S., J. K. Bagdon, E.S. Hesketh and R.L. Kellogg. 2011. Pesticide Risk Indicators Used in CEAP Cropland Modeling. USDA NRCS. Amherst, MA.

Plotkin, S., J. K. Bagdon and E.S. Hesketh. October, 2020. CEAP Pesticide Properties Database. USDA NRCS. Amherst, MA.

Wetzel, R.G. 2001. Limnology Lake and River Ecosystems. Third Edition. Academic Press.

WHO. 1998. Guidelines for Drinking Water. 2nd. Edition. Vol.2 Health Criteria and Other Supporting Information. Geneva. World Health Organization. Geneva, Switzerland.

Williams, J. R., W. L. Harman, M. Magre, U. Kizil, J. A. Lindley, G. Padmanabhan, and E. Wang. 2006. APEX Feedlot Water Quality Simulation. *Trans. ASAE* 49(1): 61-73.

Williams, J. R., R. C. Izaurralde, and E. M. Steglich. 2008. Agricultural Policy/Environmental eXtender Model: Theoretical Documentation Version 0604. BREC Report # 2008-17. Temple, TX: Texas AgriLIFE Research, Texas A&M University, Blackland Research and Extension Center. Available at: http://epicapex.brc.tamus.edu/downloads/user-manuals.aspx. Accessed 31 January 2010.

Zavaleta, J.O. 1992. Toxicological Basis for Drinking Water: Unreasonable Risk to Health Values. *J. of the American College of Toxicology*. Vol. 11(3): 325-329.