Is Protecting Aquatic Life from Pesticides Sufficient to Ensure Human Health Protection in Sources of Drinking Water?

Kelly D. Moran, Ph.D., TDC Environmental, LLC

Bonny Starr, P.E., Starr Consulting

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Abstract

California water and pesticides regulators have long operated under the informal assumption that programs to protect aquatic life from currently used pesticides will also ensure the safety of surface water drinking water sources. This paper examines the scientific validity of this assumption for the agricultural pesticides in California's Central Valley by comparing water quality regulatory values and benchmarks ("reference values") for human health with those for aquatic life. Because numeric water quality criteria and other numeric regulatory values established for water quality protection exist for only a handful of currently used pesticides, the comparison relies heavily on US EPA pesticides human health and aquatic life benchmarks.

For acute endpoints, both human health and aquatic life reference values typically use a one-day exposure time frame, but chronic endpoint exposure periods differ, with aquatic life exposure periods (4 to 60 days) usually shorter than human health exposure periods (annual).

The evaluation looked in detail at 301 agricultural pesticides with human health reference values. Of these 301 pesticides, only 46% had aquatic life reference values that were equal to or lower than the human health reference value. For 54% of these pesticides, either no aquatic life reference value existed or the aquatic life reference value was higher than the human health reference value. In these cases, aquatic life protection actions would not suffice to protect human health.

INTRODUCTION

Drinking water quality protection is among California's highest priorities for its water quality programs. This is evident in the State Water Quality Control Board's (State Water Board's) mission, which is "to preserve, enhance, and restore the quality of California's water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations."

California draws its drinking water from both surface waters and groundwater. Protecting these waters from pesticides pollution poses special challenges due the large number of pesticide chemicals, their inherent toxicity, and continual changes in the pesticides used.

Three major Federal laws regulate pesticides in sources of drinking water: the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), and the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). The US Environmental Protection Agency (EPA), which implements all three laws, has never integrated their implementation. Similarly, California EPA, which implements these Federal laws and additional state laws, does not have an integrated implementation framework.

In response to pesticides groundwater pollution, the California legislature passed the Pesticide Contamination Prevention Act, which establishes a special interagency framework for monitoring and management of pesticides in groundwater drinking water sources. Although no special framework exists for management of pesticides in surface water sources of drinking water, California pesticides and water quality regulators have authorities and obligations under both California and Federal law to prevent pesticides pollution of drinking water sources.

According to California Department of Pesticide Regulation (DPR) data, of the >1,000 currently California registered pesticide chemicals,[1] 927 were reported sold in 2015,[2] and about 300 were reported used in volumes >5,000 pounds statewide.[3] Pesticides flow into sources of drinking water from drift, with seepage and discharges from flooded pesticide-treated fields, with runoff from agricultural and urban areas, and in wastewater treatment plant effluent. The human health hazard posed by a pesticide in drinking water depends on two pesticide-specific factors: the pesticide's inherent toxicity and the exposure level.

California water and pesticides regulators have long operated under the informal assumption that programs to protect aquatic life from pesticides will also ensure human health protection in California's surface water sources of drinking water. This paper examines the scientific validity of this assumption for currently used pesticides.

REFERENCE VALUES

Water quality managers generally use available numeric reference values to facilitate determination if a currently used pesticide detected in surface water may indicate a potential human health or aquatic life risk. Comparing the reference values for human health to those for aquatic life provides insights as to whether aquatic-life protection decisions based on available reference values will also suffice to protect human health. Available reference values include regulatory standards and values and US EPA pesticides benchmarks.

Standards for Currently Used Pesticides in Sources of Drinking Water

The Clean Water Act established the national policy prohibiting the discharge of toxic pollutants in toxic amounts. (33 United States Code 1251). To implement this policy, California water quality protection programs have adopted both narrative and numeric standards for pesticides in surface waters. Narrative objectives typically drive implementation of drinking water source protection from pesticides, as numeric water quality criteria and other numeric regulatory values established for human drinking water quality protection exist for only a handful of currently used pesticides.

Ideally, monitoring and management programs would flow directly from the narrative objective, i.e., be based on toxicity measurements. This is impossible in the case of human toxicity. No indicator organisms are available to test the toxicity of drinking water sources to humans. While bioanalytical methods may soon be available to examine one or two modes of toxicity, no method to examine the plethora of human toxicity endpoints is currently reasonably foreseeable. This forces managers to use pesticide-specific values to implement the narrative human toxicity objective.

Tables 1 and 2 summarize the fresh water numeric water quality regulatory values for pesticides currently registered for use in California. These include values adopted under the CWA, the SDWA, and related state laws, but exclude location-specific values that may have been adopted by California Regional Water Quality Control Boards (e.g., water quality objectives, TMDL targets). FIFRA and California pesticides law do not involve the establishment of numeric regulatory values for pesticides in surface water.

Under the CWA, US EPA establishes both human health and aquatic life protection regulatory values for current pesticides in surface water (see Table 1). These include enforceable standards (in bold) and national recommended criteria. CWA human health regulatory values are designed for protection of humans consuming both surface water and organisms that live within surface

[1] DPR 2017. List of "Actively Registered AI's by Common Name." Downloaded August 31, 2017.
[2] DPR 2017. Pounds Sold Report. Year 2016. Generated July 11, 2017.
[3] DPR 2017. Pesticide Use Reporting System. Report generated August 31, 2017.

waters (Human Health columns in Table 1). A separate set of CWA human health regulatory values (not included here) exists for consumption of organisms only from waters that are not sources of drinking water. CWA aquatic life protection values are designed to protect aquatic ecosystems (Aquatic Life columns in Table 1).

The science-based values in Table 1 only have regulatory force when adopted as enforceable standards in state or region-specific regulatory documents. For various legal reasons, US EPA Region 9 established California's CWA pesticides water quality standards in the year 2000 (known as the California Toxics Rule [CTR][4]) (bold values in Table 1). US EPA CWA standards for pesticides chemicals that are not in this regulation and science-based CWA water quality criteria updates since the regulation's adoption are not currently part of California's CWA regulatory program.

Table 1. Clean Water Act Water Quality Criteria for Current Use Pesticides (µg/L)

	Human Health (for consumption of water and organisms)		Aquatic Life (fresh water)	
Pesticide	**Current Enforceable (CTR)**	**Current US EPA Recommended**	**Criterion Maximum Concentration (CMC)**	**Criterion Continuous Concentration (CCC)**
1,3-dichloropropene	**10**	0.27	--	--
Acrolein	**320**	3	3	3
Carbaryl	--	--	2.1	2.1
Chlorpyrifos	--	--	0.083	0.041
2,4-D	--	1,300	--	--
Diazinon	--	--	0.17	0.17
Endosulfan	**110**	20	**0.22**	**0.056**
Malathion	--	--	--	0.1
Methyl bromide	**48**	100	--	--
Pentachlorophenol	**0.28**	0.03	**19**	**15**
Phenol	**21,000**	4,000	--	--

Bold Values = Adopted California Regulatory Values from US EPA California Toxics Rule (40 CFR Part 131)
Sources: US EPA National Recommended Water Quality Criteria (https://www.epa.gov/wqc/national-recommended-water-quality-criteria accessed August 2017) and 40 CFR Part 131.

Under the SDWA and under California law, US EPA and the state of California establish human health protection regulatory values for current pesticides in drinking water sources (Table 2). Two types of Federal (SDWA) regulatory values exist: Maximum Contaminant Levels (MCLs) and Health Advisories (HAs).[5] HAs serve as the technical guidance for unregulated drinking water contaminants to assist Federal, State and local officials, and managers of public or community water systems in protecting public health as needed. They are not to be construed as legally enforceable Federal standards.[5] However, they are included in this paper as regulatory levels, because if they are exceeded actions need to be considered to protect public health. In addition to adopting Federal MCLs, California has established additional and more stringent drinking water source regulatory values under state law to address California-specific situations.

[4] 40 CFR Part 131
[5] US EPA 2018. 2018 Edition of the Drinking Water Standards and Health Advisories Tables (EPA 822-F-18-001) https://www.epa.gov/dwstandardsregulations/2018-drinking-water-standards-and-advisory-tables

These values include state-specific MCLs,[6] Notification Levels (NLs),[7] and Archived Advisory Levels (AALs).[8,9]

The relatively small number of SDWA and CWA human health regulatory standards for current use pesticides in surface waters is a direct consequence of differing data requirements for the implementation of the SDWA, CWA, and FIFRA. Pesticide registration data requirements established under FIFRA, though many and expensive for registrants, do not provide sufficient data to meet adopted SDWA and CWA requirements for establishing regulatory standards under those laws. Resource limitations also play a role in the inability of these regulatory programs to keep pace with the changing pesticides market.

Filling the Management Gap – US EPA Human Health Benchmarks for Pesticides

Recognizing the nation's need to identify the potential for current use pesticides to cause human health hazards in drinking water supplies, in the 2010s, US EPA developed Human Health Benchmarks for Pesticides (HHBPs).[10] This represented the first US EPA step toward integration of its SDWA, CWA, and FIFRA implementation programs. These values are designed to fill the gaps in available Safe Drinking Water Act regulatory values. To provide smooth integration with the SDWA, the HHBPs are calculated using the same methods that US EPA uses to calculate SDWA HAs. US EPA updates HHBPs periodically. The most recent update, reflecting 394 HHBPs for pesticides and pesticide degradates was published in January 2017.

Together, the SDWA MCLs, HAs, California regulatory values, and the US EPA HHBPs provide a means to identify potential human health risks in sources of drinking water. Thanks to the development of the HHBPs, most common currently used pesticides now have a science-based drinking water reference value.

US EPA has also developed similar benchmarks for pesticides hazards to aquatic life, the "Aquatic Life Benchmarks for Pesticide Registration" (ALBs).[11] The most recent update, reflecting 584 ALBs for pesticides and pesticide degradates was published in late 2017. Benchmarks do not exist for all pesticides due to lack of relevant toxicity data (e.g., a data gap for aquatic invertebrates), because US EPA has not yet invested in completing the data reviews necessary for development of a benchmark, or because US EPA's evaluation of toxicity data concluded that the chemical is relatively non-toxic.

Despite the general tendency to prioritize aquatic life protection in management approaches, some California agencies do use both sets of benchmarks. For example, California Department of Pesticide Regulation's (DPR's) Surface Water Monitoring Prioritization Model can be run with either set of benchmarks.[12]

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[6] California State Water Resources Control Board Division of Drinking Water 2018. Maximum Contaminant Levels and Regulatory Dates for Drinking Water, U.S. EPA vs. California
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chemicalcontaminants.html
[7] California State Water Resources Control Board Division of Drinking Water 2018. Drinking Water Notification Levels and Response Levels: An Overview
https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NotificationLevels.html
[8] California Department of Public Health (CDPH) 2010. CDPH's Archived Advisory Levels for Drinking Water
https://www.waterboards.ca.gov/water_issues/programs/tmdl/records/state_board/2010/ref3729.pdf
[9] While some information sources describe NLs and AALs as non-regulatory, they have regulatory function as exceeding these values requires actions by drinking water suppliers.
[10] US EPA Human Health Benchmarks for Pesticides (web resource) (updated January 2017)
https://iaspub.epa.gov/apex/pesticides/f?p=HHBP:home:1871379433268262
[11] US EPA Office of Pesticide Programs Aquatic Life Benchmarks (web resource) (August 2017)
https://iaspub.epa.gov/apex/pesticides/f?p=HHBP:home:1871379433268262
[12] DPR 2015. SWPP Monitoring Prioritization Model User Manual (Version 3.0)

Table 2. Safe Drinking Water Act and California State Drinking Water Source Regulatory Standards for Current Pesticides (µg/L)

Pesticide	Primary MCL[a]	Secondary MCL[a]	Health Advisory (Type)[c]	Notification Level	Archived Advisory Level
2,4-D	70	--	300 (10-day) 1,000 (1-day)	--	--
Atrazine	1 (CA)	--		--	--
Captan	--	--		--	15
Carbaryl	--	--	1,000 (1-day) 40 (Cancer)[b]	--	700
Chloropicrin	--	--		--	50
Chlorpropham (CIPC)	--	--		--	1,200
Diazinon	--	--	20 (1-day) 1 (Lifetime)	1.2	--
p-Dichlorobenzene	5 (CA)	--	11,000 (1-day) 75 (Lifetime)	--	--
1,3-Dichloropropene	0.5 (CA)	--	30 (1-day) 0.4 (Cancer)	--	--
Dimethoate	--	--		--	1
Diquat	20	--		--	--
Endothall	100	--	800 (1-day) 50 (Lifetime)	--	--
Formaldehyde	--	--	5,000 (10-day) 10,000 (1-day) 1,000 (Lifetime)	100	--
Glyphosate	700	--	20,000 (1-day)	--	--
Malathion	--	--	200 (1-day) 500 (Lifetime)	--	160
Methylisothiocyanate (degradate)	--	--		--	190
N-methyl dithiocarbamate	--	--		--	0.19
Oxamyl	50 (CA)	--	10 (1-day)	--	--
Pentachloronitrobenzene (PCNB)	--	--		--	20
Pentachlorophenol	1	--	300 (10-day) 1,000 (1-day) 40 (Lifetime) 0.09 (Cancer)	--	--
Phenol	--	--	6,000 (1-day) 2,000 (Lifetime)	--	4,200
Propoxur (Baygon)	--	--	40 (1-day) 3 (Lifetime)	--	30
Simazine	4	--		--	--
Thiobencarb	70 (CA)	1 (CA)		--	--

[a]If both California and Federal MCLs exist and are not identical, the lower value is provided. California MCLs are identified with (CA).
[b]For cancer used 10^{-6} risk for consistency with California laws and regulations (e.g., Proposition 65).
[c]10-day HAs that are identical to 1-day HAs are not noted in this table.
Sources: US EPA 2018. 2018 Edition of the Drinking Water Standards and Health Advisories Tables. EPA 822-F-18-001.; California State Water Board Division of Drinking Water 2018. Drinking Water Notification Levels and Response Levels: An Overview.; CDPH 2010. Archived Advisory Levels for Drinking Water; California State Water Board Division of Drinking Water 2018. Maximum Contaminant Levels and Regulatory Dates for Drinking Water, U.S. EPA vs. California

Time Frames Associated with Human Health and Aquatic Life Reference Values

All water quality standards and benchmarks are derived from toxicity data associated with specific exposure durations. Most standards and benchmarks include an exposure time frame, but some do not. Table 3 summarizes time frames that are specified in association with pesticide water quality standards and benchmarks and (where applicable) time frames used for compliance determination.

Table 3. Time Frames Associated with Pesticide Water Quality Standards and Benchmarks
(Where no specified value, common practice provided in italics)

Category	Acute (Short-Term)	Chronic/Cancer (Long-Term)
Clean Water Act Water Quality Criteria – Aquatic Life	1 hour	4 days
Clean Water Act Water Quality Criteria – Human Health		Not specified *(30 days)*
Maximum Contaminant Level	Any confirmed exceedance*	Annual Average
Health Advisory	1 day or 10 days (specified in listing)	Not specified *(Annual Average)*
Notification Level/Archived Advisory Level	Any confirmed exceedance*	Annual Average
Human Health Benchmarks for Pesticides	1 day	Not specified *(Annual Average)*
Aquatic Life Benchmarks for Pesticide Registration	Not specified *(1 day)*	Not specified *(varies)*

*A confirmed exceedance requires a response action but may not require use of the water source to be discontinued.
Sources: US EPA National Recommended Water Quality Criteria; California Code of Regulations Title 22 Sections 64444 and 64449; US EPA 2018. 2018 Edition of the Drinking Water Standards and Health Advisories Tables. EPA 822-F-18-001.; Drinking Water Notification Levels and Response Levels: An Overview.; CDPH 2010. Archived Advisory Levels for Drinking Water; US EPA Human Health Benchmarks for Pesticides (web resource) (updated January 2017); US EPA Office of Pesticide Programs Aquatic Life Benchmarks (web resource) (August 2017).

Clean Water Act water quality criteria for aquatic life protection specify associated time frames: Criterion Maximum Concentration – 1 hour; Criterion Continuous Concentration – 4 days.[13] Although Clean Water Act human health criteria do not specify implementation time frames, based on EPA guidance, they are implemented based on 30-day averages.[14] These time frames do not directly correlate with the human and aquatic toxicity testing that underlies these values. Anecdotal information suggests that these time frames

> "*Although the human health ambient water quality criteria (AWQC) are based on chronic health effects data (both cancer and non-cancer effects), the criteria are intended to also be protective against adverse effects that may reasonably be expected to occur as a result of elevated acute or short-term exposures. That is, through the use of conservative assumptions with respect to both toxicity and exposure parameters, the resulting AWQC should provide adequate protection not only for the general population over a lifetime of exposure, but also for special subpopulations who, because of high water or fish intake rates, or because of biological sensitivities, have an increased risk of receiving a dose that would elicit adverse effects. The Agency recognizes that there may be some cases where the AWQC based on chronic toxicity may not provide adequate protection for a subpopulation at special risk from shorter-term exposures. The Agency encourages States, Tribes, and others employing the 2000 Human Health Methodology to give consideration to such circumstances in deriving criteria to ensure that adequate protection is afforded to all identifiable subpopulations.*"
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> US EPA (2013) "Human Health Ambient Water Quality Criteria and Fish Consumption Rates: Frequently Asked Questions"

[13] US EPA National Recommended Water Quality Criteria (web resource, August 2017) https://www.epa.gov/wqc/national-recommended-water-quality-criteria
[14] US EPA Office of Water 2010. NPDES Permit Writers' Manual. EPA-833-K-10-001.

were set to be deliberately conservative to be protective and recognizing that most monitoring regimes are not (due to cost) conducted with a frequency and sample duration that reflects actual environmental exposures.

While Federal MCLs and California MCLs, NLs, and AALs are generally implemented on the basis of annual average concentrations, any single confirmed exceedance has consequences. Upon any confirmed exceedance of one of these levels, actions are required, such as increased monitoring or public notification. Significant exceedances and trends suggesting the likelihood of continued exceedances may trigger additional evaluation of source water protection options, treatment options, and potential alternative supplies.

Short-term US EPA Safe Drinking Water Act HAs specify their time frames (1 day or 10 days).[15] Similarly, acute HHBPs have a specified time frame of 1 day. Lifetime and cancer HAs and chronic HHBPs do not have specified time frames. The applicable time frame for these chronic human toxicity values depends on the sensitive life stage that is the basis of the level and may be as short as one year (e.g., infants). Typically, annual average concentrations are compared to these chronic human health reference values. For example, in pesticides risk assessments, US EPA Office of Pesticide Programs (OPP) uses annual mean water concentrations (highest single-year annual mean in 10 years of modeled exposure) to evaluate chronic human health risks from pesticides in drinking water supplies. For cancer risks, longer time frames may be used, such as US EPA OPP's use of the estimated 30-year mean concentration to evaluate drinking water cancer risks.

Aquatic Life Benchmarks for Pesticide Registration do not list specific timeframes.[16] Acute values are usually based on data from short-term tests (i.e., 2-4 days for fish and aquatic invertebrates, up to 10 days for plants). Chronic values are usually based on life-cycle tests with species-specific durations (typically in the range of 10-30 days). Typically, to be protective, time frames used with these values should be no longer than the toxicity test duration, but there are exceptions. For example, US EPA OPP ecological risk assessments use estimated one-day concentrations to evaluate potential acute aquatic toxicity risks – a time frame shorter than most underlying toxicity data – but use 60-day mean concentrations to examine potential chronic risks, which is longer than the exposure period in many chronic toxicity tests.

METHODS

This analysis used as its starting point the Central Valley Water Board list of agricultural pesticides that may be used in California's Central Valley, called the "Irrigated Lands Regulatory Program Pesticides Evaluation Protocol Executive Officer List of Pesticides."[17] This list of 373 pesticides includes pesticides registered in California as of October 31, 2016 that were identified as having potential to be used in agriculture.[18] The list excludes substances considered to be low toxicity, like oils, clays, polymers, sulfur, solvents, soaps, petroleum, biopesticides, most mineral salts, adjuvants, and pheromones. To avoid potentially inaccurate comparisons due to chemical form changes in the environment, 20 metals and inorganic salts were excluded from the analysis. For completeness, the Water Board list was supplemented to add seven pesticides used only on rice (which were omitted from the Water Board list) and six pesticide degradates from the

[15] US EPA 2018. 2018 Edition of the Drinking Water Standards and Health Advisories Tables. EPA 822-F-18-001.
[16] See footnotes in US EPA Office of Pesticide Programs Aquatic Life Benchmarks https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk
[17] Central Valley Water Board 2016. Irrigated Land Regulatory Program. Prioritizing and Selecting Pesticides for Surface Water Monitoring. (ILRP Pesticides Evaluation Protocol.)
[18] Pesticides in the California DPR product/label database with uses in the "agricultural crops" site group category.

Central Valley Water Board Executive Officer List of Degradates[19] that have human health reference values. This process created a list of 366 agricultural pesticides and degradates.

For purposes of this analysis, "reference value" was defined to include CWA, SDWA, and California regulatory values (Tables 1 and 2) supplemented by US EPA pesticides benchmarks.[20] Where multiple values exist for the same pesticide (e.g., the pesticide had values for different types of aquatic organisms or the pesticide had both a California MCL and a US EPA HHBP), the lowest human health value and the lowest aquatic life value were selected.

To address nomenclature inconsistency among reference lists, when no reference value was initially identified, the search was expanded to include synonyms. Two searches for synonyms were done, using DPR's chemical list search tool[21] and the "synonyms" link from the US EPA pesticide search web page.[22]

Available reference values were obtained from these data sources and compiled into a single table (see Table 4, attached).

RESULTS AND DISCUSSION

Human health reference values were identified for 301 of the 366 agricultural pesticides. The remaining 65 pesticides did not have human health reference values and consequently were excluded from further analysis since no comparison would be possible. (Excluded pesticides have brown shading in Table 4).

Table 5 summarizes the outcome of the reference value comparison. Both aquatic life and human health reference values were identified for 235 pesticides; for the remaining 66, no aquatic life reference value was identified.

Table 5. Summary Comparison of Human Health and Aquatic Life Reference Values for Current Use Agricultural Pesticides in California's Central Valley

Category	Number	Fraction of Evaluated Pesticides
Human Health Reference Value, but no Aquatic Life Reference Value	66	22%
Lowest Human Health Reference Value < Lowest Aquatic Life Reference Value	97	32%
Lowest Human Health Reference Value > Lowest Aquatic Life Reference Value	136	45%
Lowest Human Health Reference Value = Lowest Aquatic Life Reference Value	2	1%
Pesticides Evaluated	301	
Pesticides excluded due to lack of human health reference value	*65*	

For 97 of the 235 pesticides, the lowest human health reference value was less than (a lower concentration than) the lowest aquatic life reference value. For 136 pesticides, the lowest aquatic life reference value was less than (a lower concentration than) the lowest human health reference

[19] See Attachment 1 of Central Valley Water Board 2016. Irrigated Land Regulatory Program. Prioritizing and Selecting Pesticides for Surface Water Monitoring.
[20] US EPA 2017 Human Health Benchmarks for Pesticides (web resource) (updated January 2017) https://iaspub.epa.gov/apex/pesticides/f?p=HHBP:home:1871379433268262 ; US EPA 2017 Office of Pesticide Programs Aquatic Life Benchmarks (web resource accessed August 2017) https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/aquatic-life-benchmarks-and-ecological-risk
[21] http://www.cdpr.ca.gov/docs/label/chemcode.htm
[22] http://iaspub.epa.gov/apex/pesticides/f?p=chemicalsearch:1:4374205614359044

value. For two pesticides (Acrolein, Thiobencarb), the lowest human health reference value and the lowest aquatic life reference value were equal.

Only 64% of the pesticides examined had both human health and aquatic life reference values. About 36% of the evaluated pesticides did not have both human health and aquatic life reference values. Agencies that develop these reference values do not automatically develop reference values for every pesticide. Due to resource constraints and data gaps, agencies prioritize their resources toward those pesticides that based on available data appear to pose the greatest hazards to human health or aquatic life. The lack of a reference value might indicate data gaps or it might signal that the pesticide has relatively low toxicity to aquatic life or to humans.

CONCLUSIONS

For the group of agricultural pesticides evaluated, where human health reference values exist (301 pesticides), only 46% had aquatic life reference values that were equal to or lower than the human health reference value. For 54% of these pesticides, either no aquatic life reference value existed or the aquatic life reference value was higher. In these cases, aquatic life protection actions would not suffice to protect human health.

No aquatic life reference value existed for 22% of the pesticides. Pesticides without aquatic life reference values are usually excluded from aquatic life protection management systems due to the lack of a value.

For acute endpoints, both human health and aquatic life reference values typically use a one-day exposure time frame, but chronic endpoint exposure periods differ, with aquatic life exposure periods (4 to 60 days) usually shorter than human health exposure periods (annual). In general, evaluation based on shorter exposure time frames is more protective, suggesting that where aquatic reference values are lower than human health reference values, surface water management for aquatic life protection purposes would suffice to protect drinking water supplies.

For human health standards and benchmarks with unspecified time frames, the common practice of using one day for acute and annual average for chronic appears appropriate for screening-level evaluations. Detailed evaluation of a specific pesticide in comparison to a standard or benchmark without a specified time frame should consider the time frame associated with the toxicity data underlying the pesticide-specific standard or benchmark, particularly in cases potentially leading to management actions (e.g., incidents of measured or projected exceedances).

Table 4. Comparison of Human Health and Aquatic Life Reference Values for Agricultural Pesticides

Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Central Valley Water Board Irrigated Lands Regulatory Program Pesticides Evaluation Protocol Executive Officer List of Pesticides							
(S) Cypermethrin (Zeta-Cypermethrin)	150	HHBP	Acute, Children	0.00059	ALB	Invertebrates, Chronic	
1,3-Dichloropropene	0.27	US EPA NRWQC	Cancer	45	ALB	Invertebrates, Acute	HA = 0.4; CA Primary MCL = 0.5; US EPA CTR = 10
1-methylcyclopropene	--						
1-Naphthaleneacetamide	1600	HHBP	Chronic, General Population	--			
2-(2,4-DP), Dimethylamine Salt	--						
2,4-D	70	US EPA Primary MCL		12500	ALB	Fish, Acute	
2,4-D, 2-Ethylhexyl Ester	--						
2,4-D, Butoxyethanol Ester	--						
2,4-D, Diethanolamine Salt	--						
2,4-D, Dimethylamine Salt	--						
2,4-D, Isooctyl Ester	--						
2,4-D, Isopropyl Ester	--						
2,4-D, Triisopropanolamine salt	--						
2,4-DB Acid (2, 4 - DBA)	200	HHBP	Chronic, General Population	932	ALB	Vascular Plant	
2,4-DP-P, Dimethylamine Salt	230	HHBP	Chronic, General Population	77	ALB	Non-Vascular Plant	
2,4-DP-p Isooctyl Ester	230	HHBP	Chronic, General Population	77	ALB	Non-Vascular Plant	
2,4-xylenol	--						
3-chloro-p-toluidine hydrochloride	--						
4-(2,4-DB), Dimethylamine salt (2,4-DB DMAS)	200	HHBP	Chronic, General Population	1567	ALB	Fish, Acute	
4-aminopyridine	--						
Abamectin	3	HHBP	Chronic, General Population	0.17	ALB	Invertebrates, Acute	
Acephate	7.7	HHBP	Chronic, General Population	150	ALB	Invertebrates, Chronic	
Acequinocyl	170	HHBP	Chronic, General Population	0.98	ALB	Invertebrates, Chronic	
Acetamiprid	450	HHBP	Chronic, General Population	2.1	ALB	Invertebrates, Chronic	
Acetic Acid	--						
Acibenzolar-S-methyl	450	HHBP	Chronic, Females 13-49 years	--			
Acrolein	3	US EPA NRWQC		3	US EPA NRWQC	CCC	
Alachlor	2	US EPA Primary MCL		1.64	ALB	Non-Vascular Plant	
ADBAC (registered as four groups of alkyl dimethylbenzyl ammonium chlorides)	2800	HHBP	Chronic, General Population	--			
Aluminum phosphide	72.3	HHBP	Chronic, General Population	--			
Ametoctradin	--						
Amino Ethoxy vinyl glycine hydrochloride	--						
Aminocyclopyrachlor	17900	HHBP	Chronic, General Population	370	ALB	Invertebrates, Chronic	
Aminocyclopyrachlor, potassium salt	17900	HHBP	Chronic, General Population	370	ALB	Invertebrates, Chronic	
Aminopyralid, triisopropanolamine Salt	3000	HHBP	Chronic, General Population	1360	ALB	Fish, Chronic	
Ammonium nonanoate	--						
Ancymidol	--						
Atrazine	1	CA Primary MCL		0.001	ALB	Vascular Plant	
Azoxystrobin	1200	HHBP	Chronic, General Population	44	ALB	Invertebrates, Chronic	
Benefin (Benfluralin)	30	HHBP	Chronic, General Population	1.9	ALB	Fish, Chronic	
Bensulide	30	HHBP	Chronic, General Population	290	ALB	Invertebrates, Acute	
Bentazon, sodium salt	18	CA Primary MCL		4500	ALB	Non-Vascular Plant	
Beta-conglutin	--						
Beta Cyfluthrin	100	HHBP	Acute, Children	0.034	ALB	Fish, Acute	
Bifenazate	60	HHBP	Chronic, General Population	150	ALB	Invertebrates, Chronic	
Bifenthrin	70	HHBP	Acute, Children	0.0013	ALB	Invertebrates, Chronic	
Borax	--						
Boric Acid	--						
Boscalid	1400	HHBP	Chronic, General Population	116	ALB	Fish, Chronic	
Bromacil	70	HA	Lifetime	6.8	ALB	Non-Vascular Plant	
Bromadiolone	--						
Bromethalin	--						
Bromoxynil heptanoate	0.311	HHBP	Cancer	14.5	ALB	Fish, Acute	
Bromoxynil octanoate	0.311	HHBP	Cancer	2.5	ALB	Invertebrates, Chronic	
Buprofezin	21	HHBP	Chronic, General Population	--			
Capric Acid	--						
Caprylic Acid	--						
Captan	15	AAL		13.1	ALB	Fish, Acute	
Carbaryl	40	HA	Lifetime	0.5	ALB	Invertebrates, Chronic	AAL = 700; US NRWQC (aquatic life, CMC & CCC) = 2.1
Carboxin	700	HA	Lifetime	370	ALB	Non-Vascular Plant	
Carfentrazone-ethyl	200	HHBP	Chronic, General Population	--			
Chlorantraniliprole	10100	HHBP	Chronic, General Population	4.5	ALB	Invertebrates, Chronic	
Chlorfenapyr	300	HHBP	Acute, Children & Chronic, General Population	2.915	ALB	Invertebrates, Acute	
Chlorflurenol, methyl ester	600	HHBP	Chronic, General Population	--			
Chlormequat chloride	300	HHBP	General Population	--			
Chlorophacinone	--						
Chloropicrin	50	AAL		5.5	ALB	Fish, Acute	

Table 4. Comparison of Human Health and Aquatic Life Reference Values for Agricultural Pesticides

Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Chlorothalonil	1.5	HA	Cancer	0.6	ALB	Invertebrates, Chronic	
Chlorpropham	300	HHBP	Chronic, General Population	--			AAL = 1,200
Chlorpyrifos	2	HA	Lifetime	0.04	ALB	Invertebrates, chronic	US EPA NRWQC (aquatic life, CCC) = 0.041
Chlorsulfuron	300	HHBP	Chronic, General Population	0.35	ALB	Non-Vascular Plant	
Chlorthal-dimethyl	--						
Clethodim	2000	HHBP	Chronic, General Population	2	ALB	Fish, Chronic	
Clofentezine	0.851	HHBP	Cancer	6	ALB	Fish, Chronic	
Clopyralid, monoethanolamine salt	960	HHBP	Chronic, General Population	56500	ALB	Invertebrates, Acute	
Clopyralid, triethylamine salt	960	HHBP	Chronic, General Population	56500	ALB	Invertebrates, Acute	
Clothianidin	630	HHBP	Chronic, General Population	1.1	ALB	Invertebrates, Chronic	
Copper	Metals/Salts Excluded						
Copper ammonium complex	Metals/Salts Excluded						
Copper citrate chelate	Metals/Salts Excluded						
Copper diammonium diacetate complex	Metals/Salts Excluded						
Copper ethanolamine complexes, mixed	Metals/Salts Excluded						
Copper ethylenediamine complex	Metals/Salts Excluded						
Copper gluconate chelate	Metals/Salts Excluded						
Copper hydroxide	Metals/Salts Excluded						
Copper octanoate	Metals/Salts Excluded						
Copper oxide (ous)	Metals/Salts Excluded						
Copper oxychloride	Metals/Salts Excluded						
Copper sulfate (basic)	Metals/Salts Excluded						
Copper sulfate (pentahydrate)	Metals/Salts Excluded						
Copper triethanolamine complex	Metals/Salts Excluded						
Cryolite	--						
Cyantraniliprole	60	HHBP	Chronic, General Population	6.56	ALB	Invertebrates, Chronic	
Cyazofamid	6070	HHBP	Chronic, General Population	53.5	ALB	Fish, Acute	
Cyclanilide	40	HHBP	Chronic, General Population	--			
Cycloate	30	HHBP	Chronic, General Population	1300	ALB	Invertebrates, Acute	
Cyflufenamid	280	HHBP	Chronic, General Population	--			
Cyfluthrin	100	HHBP	Acute, Children	0.0074	ALB	Invertebrates, Chronic	
Cymoxanil	5	HHBP	Chronic, General Population	--			
Cypermethrin	150	HHBP	Acute, Children	0.069	ALB	Invertebrates, Chronic	
Cyprodinil	170	HHBP	Chronic, General Population	8	ALB	Invertebrates, Chronic	
Cyromazine	3000	HHBP	Chronic, General Population	310	ALB	Invertebrates, Chronic	
Daminozide	3.7	HHBP	Cancer	35500	ALB	Invertebrates, Acute	
Dazomet	--						
Dichlorvos (DDVP)	3	HHBP	Chronic, General Population	0.0058	ALB	Invertebrates, Chronic	
Deltamethrin	30	HHBP	Acute, Children	0.0041	ALB	Invertebrates, Chronic	
Desmedipham	300	HHBP	Chronic, General Population	--			
Diazinon	1	HA	Lifetime	0.105	ALB	Invertebrates, Acute	NL = 1.2; US EPA NRWQC (aquatic life CMC & CCC) = 0.17
Dicamba	4000	HA	Lifetime	61	ALB	Non-Vascular Plant	
Dicamba, dimethylamine salt	4000	HA	Lifetime	488500	ALB	Fish, Acute	
Dicamba, sodium salt	4000	HA	Lifetime	17300	ALB	Invertebrates, Acute	
Dichlobenil	60	HHBP	Chronic, General Population	30	ALB	Non-Vascular Plant	
Dicloran (Dichloran)	16	HHBP	Chronic, General Population	--			
DDAC, Didecyl dimethyl ammonium chloride	600	HHBP	Chronic, General Population	--			
Difenoconazole	60	HHBP	Chronic, General Population	5.6	ALB	Invertebrates, Chronic	
Diflubenzuron	100	HHBP	Chronic, General Population	0.00025	ALB	Invertebrates, Chronic	
Diflufenzopyr, sodium salt	1700	HHBP	Chronic, General Population	--			
Diglycolamine Salt of 3,6-Dichloro-o-anisic acid	--						
Dikegulac sodium	--						
Dimethenamid-P	300	HHBP	Chronic, General Population	8.9	ALB	Vascular Plant	
Dimethoate	1	AAL		0.5	ALB	Invertebrates, Chronic	
Dimethomorph	600	HHBP	Chronic, General Population	110	ALB	Invertebrates, Chronic	
Dinotefuran	6000	HHBP	Chronic, General Population	6360	ALB	Fish, Chronic	
Dioctyl dimethyl ammonium chloride	--						
Diphacinone	10	HHBP	Acute, Children	--			
Diphacinone, sodium salt	10	HHBP	Acute, Children	--			
Diphenylamine	600	HHBP	Chronic, General Population	--			

Table 4. Comparison of Human Health and Aquatic Life Reference Values for Agricultural Pesticides

Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Diquat Dibromide (Diquat)	20	US EPA Primary MCL		0.75	ALB	Non-Vascular Plant	
Disodium octaborate tetrahydrate	Metals/Salts Excluded						
Dithiopyr	--						
Diuron	2	HA	Cancer	2.4	ALB	Non-Vascular Plant	
Dodine	100	HHBP	Chronic, General Population	0.95	ALB	Non-Vascular Plant	
D-trans allethrin	--						
Emamectin Benzoate	0.48	HHBP	Chronic, General Population	--			
Endosulfan	20	US EPA NRWQC		0.01	ALB	Invertebrates, Chronic	US EPA CTR Human Health = 110; US EPA NRWQC (Aquatic Life, CCC) = FW 0.056; SW = 0.0087
Endothall, dipotassium salt	50	HA	Lifetime	610	ALB	Vascular Plant	US EPA Primary MCL = 100
Endothall, Mono (N,N-dimethylalkylamine) salt	50	HA	Lifetime	2.3	ALB	Invertebrates, Chronic	US EPA Primary MCL = 100
EPTC (Ethyl dipropylthiocarbamate)	300	HHBP	Chronic, General Population	800	ALB	Invertebrates, Chronic	
Esbiothrin	--						
Esfenvalerate	12	HHBP	Acute, Children & Chronic, General Population	0.017	ALB	Invertebrates, Chronic	
Ethalfluralin	0.36	HHBP	Cancer	0.4	ALB	Fish, Chronic	
Ethephon	400	HHBP	Chronic, General Population	2500	ALB	Non-Vascular Plant	
Ethofumesate	2000	HHBP	Chronic, Females 13-49 years	300	ALB	Invertebrates, Chronic	
Ethoprop	1.14	HHBP	Cancer	0.8	ALB	Invertebrates, Chronic	
Etofenprox	240	HHBP	Chronic, General Population	0.17	ALB	Invertebrates, Chronic	
Etoxazole	290	HHBP	Chronic, General Population	0.13	ALB	Invertebrates, Chronic	
Famoxadone	9	HHBP	Chronic, General Population	--			
Fenamidone	181	HHBP	Chronic, General Population	4.7	ALB	Fish, Chronic	
Fenarimol	40	HHBP	Chronic, General Population	100	ALB	Vascular Plant	
Fenazaquin	300	HHBP	Chronic, General Population	--			
Fenbuconazole	8.91	HHBP	Cancer	--			
Fenbutatin-oxide	110	HHBP	Chronic, General Population	0.31	ALB	Fish, Chronic	
Fenhexamid	1100	HHBP	Chronic, General Population	101	ALB	Fish, Chronic	
Fenoxaprop-p-ethyl	16	HHBP	Chronic, General Population	155	ALB	Fish, Acute	
Fenpropathrin	110	HHBP	Acute, Children	0.064	ALB	Invertebrates, Chronic	
Fenpyrazamine	2000	HHBP	Chronic, General Population	11	ALB	Vascular Plant	
Fenpyroximate	300	HHBP	Chronic, General Population	0.016	ALB	Fish, Chronic	
Ferric sodium EDTA	--						
Ferrous sulfate	Metals/Salts Excluded						
Fipronil	1	HHBP	Chronic, General Population	0.011	ALB	Invertebrates, Chronic	
Flazasulfuron	83	HHBP	Chronic, General Population	--			
Flonicamid	300	HHBP	Chronic, General Population	3000	ALB	Invertebrates, Chronic	
Fluazifop-P-Butyl	47	HHBP	Chronic, General Population	203	ALB	Fish, Chronic	
Fluazinam	70	HHBP	Chronic, General Population	0.69	ALB	Fish, Chronic	
Flubendiamide	150	HHBP	Chronic, General Population	41.5	ALB	Invertebrates, Chronic	
Fludioxonil	200	HHBP	Chronic, General Population	19	ALB	Fish, Chronic	
Fluensulfone	200	HHBP	Chronic, General Population	22	ALB	Vascular Plant	
Flumiclorac-pentyl	6000	HHBP	Chronic, General Population	94.5	ALB	Invertebrates, Acute	
Flumioxazin	100	HHBP	Chronic, General Population	0.49	ALB	Non-Vascular Plant	
Fluopicolide	1000	HHBP	Chronic, General Population	1.4	ALB	Vascular Plant	
Fluopyram	77	HHBP	Chronic, General Population	--			
Fluoxastrobin	96	HHBP	Chronic, General Population	--			
Flupyradifurone	500	HHBP	Chronic, General Population	--			
Flurecol-methyl	--						
Fluroxypyr, 1-methylheptyl ester	6000	HHBP	Chronic, General Population	56	ALB	Non-Vascular Plant	
Flurprimidol	300	HHBP	Chronic, General Population	840	ALB	Vascular Plant	
Flutolanil	3000	HHBP	Chronic, General Population	220	ALB	Fish, Chronic	
Flutriafol	300	HHBP	Chronic, General Population	310	ALB	Invertebrates, Chronic	
Fluxapyroxad	130	HHBP	Chronic, General Population	--			
Forchlorfenuron	400	HHBP	Chronic, General Population	--			
Formetanate hydrochloride	2.1	HHBP	Acute, Children	0.5	ALB	Invertebrates, Chronic	
Fosetyl-Al	16000	HHBP	Chronic, General Population	780	ALB	Vascular Plant	
Fosthiazate	6.1	HHBP	Chronic, General Population	61	ALB	Invertebrates, Chronic	
Gamma-Cyhalothrin	6	HHBP	Chronic, General Population	0.00024	ALB	Invertebrates, Acute	
Glufosinate-ammonium	40	HHBP	Chronic, General Population	72	ALB	Vascular Plant	
Glutaraldehyde	--						
Glyphosate	700	US EPA Primary MCL		11900	ALB	Vascular Plant	
Glyphosate, dimethylamine salt	700	US EPA Primary MCL		--			
Glyphosate, isopropylamine salt	700	US EPA Primary MCL		34700	ALB	Fish, Acute	
Glyphosate, monoammonium salt	700	US EPA Primary MCL		--			
Glyphosate, potassium salt	700	US EPA Primary MCL		--			
Halosulfuron-methyl (MON 1200)	600	HHBP	Chronic, General Population	--			
Hexazinone	400	HA	Lifetime	7	ALB	Non-Vascular Plant	
Hexythiazox	160	HHBP	Chronic, General Population	6.1	ALB	Invertebrates, Chronic	
Hydramethylnon	110	HHBP	Chronic, General Population	45	ALB	Fish, Acute	
Hydrogen cyanamide	0.482	HHBP	Cancer	100	ALB	Invertebrates, Chronic	
Imazalil	0.524	HHBP	Cancer	--			

Table 4. Comparison of Human Health and Aquatic Life Reference Values for Agricultural Pesticides

Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Imazalil Sulfate	0.524	HHBP	Cancer	--			
Imazamox, ammonium Salt	--						
Imazapyr, isopropylamine salt	16000	HHBP	Chronic, General Population	24	ALB	Non-Vascular Plant	
Imazethapyr	16000	HHBP	Chronic, General Population	59200	ALB	Vascular Plant	
Imazosulfuron	4800	HHBP	Chronic, General Population	1.46	ALB	Non-Vascular Plant	
Imidacloprid	360	HHBP	Chronic, General Population	1.05	ALB	Invertebrates, Chronic	
Indaziflam	100	HHBP	Chronic, General Population	--			
Indoxacarb	100	HHBP	Chronic, General Population	75	ALB	Invertebrates, Chronic	
Ipconazole	96	HHBP	Chronic, General Population	0.18	ALB	Fish, Chronic	
Iprodione	0.729	HHBP	Cancer	120	ALB	Invertebrates, Acute	
Iron Phosphate	Metals/Salts Excluded						
Isofetamid	4900	HHBP	Chronic, General Population	86	ALB	Fish, Chronic	
Isoxaben	300	HHBP	Chronic, General Population	10	ALB	Non-Vascular Plant	
Kresoxim-methyl	11	HHBP	Cancer	29.2	ALB	Vascular Plant	
Lambda-cyhalothrin	6	HHBP	Chronic, General Population	0.002	ALB	Invertebrates, Chronic	
Linuron	49	HHBP	Chronic, General Population	0.09	ALB	Invertebrates, Chronic	
Malathion	160	AAL		0.035	ALB	Invertebrates, Chronic	HA = 200 (1-day and 10 day child); US EPA NRWQC (Aquatic life, CCC) = 0.1
Maleic hydrazide	4000	HA	Lifetime	9600	ALB	Fish, Chronic	
Maleic hydrazide, potassium salt	4000	HA	Lifetime	9600	ALB	Fish, Chronic	
Mancozeb	0.532	HHBP	Cancer	47	ALB	Vascular Plant	
Mandipropamid	300	HHBP	Chronic, General Population	220	ALB	Fish, Chronic	
MCPA, 2-Ethylhexyl ester	30	HA	Lifetime	20	ALB	Vascular Plant	
MCPA, Dimethylamine salt	30	HA	Lifetime	130	ALB	Vascular Plant	
MCPA, Isooctyl ester	30	HA	Lifetime	--			
MCPP-p, dimethylamine salt	300	HHBP	Chronic, General Population	14	ALB	Non-Vascular Plant	
Mecoprop-p	--						
Mefenoxam	474	HHBP	Chronic, General Population	100	ALB	Invertebrates, Chronic	
Mefluidide, diethanolamine salt	96	HHBP	Chronic, General Population	--			
Mepiquat Chloride	1250	HHBP	Chronic, General Population	--			
Mesosulfuron-methyl	9920	HHBP	Chronic, General Population	0.64	ALB	Non-Vascular Plant	
Mesotrione	4500	HHBP	Chronic, General Population	17.7	ALB	Non-Vascular Plant	
Meta-cresol	--						
Metaflumizone	300	HHBP	Chronic, General Population	--			
Metalaxyl	--						
Metaldehyde	600	HHBP	Chronic, General Population	34500	ALB	Fish, Acute	
Metconazole	300	HHBP	Chronic, General Population	--			
Methidathion	9.6	HHBP	Chronic, General Population	0.66	ALB	Invertebrates, Chronic	
Methiocarb	--						
Methomyl	200	HA	Lifetime	0.7	ALB	Invertebrates, Chronic	
Methoxyfenozide	600	HHBP	Chronic, General Population	6.3	ALB	Invertebrates, Chronic	
Methyl anthranilate	--						
Methyl bromide	48	US EPA CTR		1300	ALB	Invertebrates, Acute	US EPA NRWQC Human Health = 100
Methyl-2,7-dichloro-9-hydroxyfluorene-9-carboxylate	--						
Metiram	0.532	HHBP	Cancer	--			
Metolachlor	700	HA	Lifetime	1	ALB	Invertebrates, Chronic	
Metrafenone	1590	HHBP	Chronic, General Population	--			
Metribuzin	70	HA	Lifetime	8.1	ALB	Non-Vascular Plant	
Milbemectin	--						
MSMA	200	HHBP	Chronic, General Population	5630	ALB	Vascular Plant	
Myclobutanil	160	HHBP	Chronic, General Population	830	ALB	Vascular Plant	
N6-benzyl adenine	--						
NAA (Naphthalene Acetic Acid)	1600	HHBP	Chronic, General Population	5100	ALB	Vascular Plant	
NAA Amonium Salt	1600	HHBP	Chronic, General Population	14900	ALB	Non-Vascular Plant	
NAA Ethyl Ester	1600	HHBP	Chronic, General Population	1340	ALB	Fish, Acute	
NAA Potassium Salt	1600	HHBP	Chronic, General Population	5100	ALB	Vascular Plant	
NAA Sodium Salt	1600	HHBP	Chronic, General Population	--			
Naled	10	HHBP	Chronic, General Population	0.045	ALB	Invertebrates, Chronic	
Napropamide	770	HHBP	Chronic, General Population	1100	ALB	Invertebrates, Chronic	
Nicosulfuron	8000	HHBP	Chronic, General Population	43000	ALB	Invertebrates, Chronic	
Nitrapyrin	200	HHBP	Chronic, General Population	--			
N-Octyl bicycloheptene Dicarboximide (MGK-264)	390	HHBP	Chronic, General Population	--			
Norflurazon	96	HHBP	Chronic, General Population	9.7	ALB	Vascular Plant	
Novaluron	70	HHBP	Chronic, General Population	0.03	ALB	Invertebrates, Chronic	
Octyl decyl dimethyl ammonium chloride	--						
Ortho-phenylphenol, sodium salt	--						
Oryzalin	4.11	HHBP	Cancer	42	ALB	Non-Vascular Plant	
Oxadiazon	--						
Oxamyl	10	HA	Acute (1-day), Children	27	ALB	Invertebrates, Chronic	CA Primary MCL = 50
Oxydemeton-methyl	0.6	HHBP	Chronic, General Population	5	ALB	Fish, Chronic	
Oxyfluorfen	0.437	HHBP	Cancer	0.29	ALB	Vascular Plant	
Oxytetracycline hydrochloride	6000	HHBP	Chronic, General Population	47450	ALB	Fish, Acute	
Oxytetracycline calcium complex	3	HHBP	Chronic, General Population	--			

Table 4. Comparison of Human Health and Aquatic Life Reference Values for Agricultural Pesticides

Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Paclobutrazol	700	HHBP	Chronic, General Population	8	ALB	Non-Vascular Plant	
Paraquat dichloride	30	HA	Lifetime	71	ALB	Vascular Plant	
PCNB, Pentachloronitrobenzene (Quintozene)	6	HHBP	Chronic, General Population	13	ALB	Fish, Chronic	AAL = 20
Pendimethalin	2000	HHBP	Chronic, General Population	5.2	ALB	Vascular Plant	
Penflufen	2400	HHBP	Chronic, General Population	--			
Penoxsulam	941	HHBP	Chronic, General Population	3	ALB	Non-Vascular Plant	
Penthiopyrad	1700	HHBP	Chronic, General Population	100	ALB	Fish, Chronic	
Permethrin	3.344	HHBP	Cancer	0.0014	ALB	Invertebrates, Chronic	
Peroxyacetic acid	--						
Peroxyoctanoic acid	--						
Phenmedipham	1500	HHBP	Chronic, General Population	--			
d-Phenothrin (Sumithrin)	40	HHBP	Chronic, General Population	0.47	ALB	Invertebrates, Chronic	
Phorate	1.1	HHBP	Chronic, General Population	0.21	ALB	Invertebrates, Chronic	
Phosmet	3	HHBP	Females 13-49 years	0.8	ALB	Invertebrates, Chronic	
Phosphine	--						
Picoxystrobin	290	HHBP	Chronic, General Population	1	ALB	Invertebrates, Chronic	
Pinoxaden	2000	HHBP	Chronic, General Population	1200	ALB	Vascular Plant	
Piperonyl butoxide	992	HHBP	Chronic, General Population	30	ALB	Invertebrates, Chronic	
Polyoxin D, zinc salt	--						
Potassium N-methyldithiocarbamate	0.19	AAL		--			
Prallethrin	50	HHBP	Acute, Children	0.65	ALB	Invertebrates, Chronic	
Prodiamine	--						
Prohexadione calcium	1000	HHBP	Chronic, General Population	12500	ALB	Invertebrates, Chronic	
Prometon	200	HA	Acute (1-day), Children	98	ALB	Non-Vascular Plant	
Prometryn	300	HHBP	Chronic, General Population	1.04	ALB	Vascular Plant	
Propamocarb hydrochloride	770	HHBP	Chronic, General Population	--			
Propargite	0.167	HHBP	Cancer	7	ALB	Invertebrates, Acute	
Propiconazole	600	HHBP	Chronic, General Population	21	ALB	Vascular Plant	
Propionic Acid	--						
Propylene oxide	6	HHBP	Chronic, General Population	42000	ALB	Fish, Acute	
Propylene glycol monolaurate	--						
Pronamide (Propyzamide)	300	HHBP	Acute, Children & Chronic, General Population	600	ALB	Invertebrates, Chronic	
Prothioconazole	60	HHBP	Chronic, General Population	--			
Pymetrozine	2.69	HHBP	Cancer	25	ALB	Invertebrates, Chronic	
Pyraclostrobin	220	HHBP	Chronic, General Population	1.5	ALB	Vascular Plant	
Pyraflufen-ethyl	0.964	HHBP	Cancer	0.89	ALB	Fish, Chronic	
Pyrethrins	280	HHBP	Chronic, General Population	0.86	ALB	Invertebrates, Chronic	
Pyridaben	30	HHBP	Chronic, General Population	0.044	ALB	Invertebrates, Chronic	
Pyridalyl	220	HHBP	Chronic, General Population	2.1	ALB	Invertebrates, Acute	
Pyrimethanil	1100	HHBP	Chronic, General Population	20	ALB	Fish, Chronic	
Pyriproxyfen	2200	HHBP	Chronic, General Population	0.015	ALB	Invertebrates, Chronic	
Pyrithiobac-sodium	--						
Pyroxsulam	6000	HHBP	Chronic, General Population	2.57	ALB	Non-Vascular Plant	
Quinchlorac	2400	HHBP	Chronic, General Population	500	ALB	Vascular Plant	
Quinchlorac, dimethylamine salt	2400	HHBP	Chronic, General Population	500	ALB	Vascular Plant	
Quinoxyfen	1000	HHBP	Chronic, General Population	13	ALB	Fish, Chronic	
Resmethrin	0.5692	HHBP	Cancer	0.14	ALB	Fish, Acute	
Rimsulfuron	755	HHBP	Chronic, General Population	11.6	ALB	Non-Vascular Plant	
S,S,S-tributyl phosphorotrithioate (Tribufos)	0.6	HHBP	Chronic, General Population	1.56	ALB	Invertebrates, Chronic	
Saflufenacil (BAS 800 H)	290	HHBP	Chronic, General Population	42	ALB	Vascular Plant	
Salicyclic acid	--						
Sethoxydim	900	HHBP	Chronic, General Population	210	ALB	Non-Vascular Plant	
Siduron	960	HHBP	Chronic, General Population	6	ALB	Invertebrates, Chronic	
Simazine	4	CA Primary MCL		2.24	ALB	Vascular Plant	
S-methoprene	--						
S-metolachlor	--						
Sodium chlorate	Metals/Salts Excluded						
Sodium cyanide	--						
Sodium metaborate tetrahydrate	Metals/Salts Excluded						
Spinetoram	159	HHBP	Chronic, General Population	--			
Spinosad	159	HHBP	Chronic, General Population	0.6	ALB	Invertebrates, Chronic	
Spirodiclofen	2.15	HHBP	Cancer	1.95	ALB	Fish, Chronic	
Spiromesifen	140	HHBP	Chronic, General Population	0.25	ALB	Invertebrates, Chronic	
Spirotetramat	300	HHBP	Chronic, General Population	100	ALB	Invertebrates, Chronic	
Streptomycin Sulfate	300	HHBP	Chronic, General Population	--			
Strychnine	--						
Sulfentrazone	900	HHBP	Chronic, General Population	28.8	ALB	Non-Vascular Plant	
Sulfometuron Methyl	1760	HHBP	Chronic, General Population	0.45	ALB	Non-Vascular Plant	
Sulfosulfuron	1500	HHBP	Chronic, General Population	1	ALB	Non-Vascular Plant	
Sulfuryl fluoride	500	HHBP	Chronic, General Population	--			
Tau-fluvalinate	30	HHBP	Acute, Children & Chronic, General Population	0.1	ALB	Invertebrates, Chronic	
TCMTB (Busan 72)	60	HHBP	Chronic, General Population	--			
Tebuconazole	190	HHBP	Chronic, General Population	12	ALB	Fish, Chronic	

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Pesticide	Lowest Human Ref. Value (ppb)	Human Health Reference Value Type	Human Health Reference Value Endpoint	Lowest Aquatic Ref. Value (ppb)	Aquatic Life Reference Value Type	Aquatic Life Reference Value Endpoint	Notes
Tebufenozide	120	HHBP	Chronic, General Population	4.3	ALB	Invertebrates, Chronic	
Tebuthiuron	500	HA	Lifetime	50	ALB	non-Vascular Plant	
Tembotrione	3	HHBP	Chronic, General Population	5.2	ALB	Non-Vascular Plant	
Terrazole (Etridiazole)	0.961	HHBP	Cancer	72	ALB	Vascular Plant	
Tetraconazole	47	HHBP	Chronic, General Population	190	ALB	Invertebrates, Chronic	
Tetramethrin	--						
Thiabendazole	210	HHBP	Chronic, General Population	42	ALB	Invertebrates, Chronic	
Thiacloprid	0.788	HHBP	Cancer	0.97	ALB	Invertebrates, Chronic	
Thiamethoxam	77	HHBP	Chronic, General Population	17.5	ALB	Invertebrates, Acute	
Thidiazuron	252	HHBP	Chronic, General Population	--			
Thiencarbazone-methyl	7490	HHBP	Chronic, General Population	0.8	ALB	Non-Vascular Plant	
Thiophanate-methyl	2.76	HHBP	Cancer	930	ALB	Vascular Plant	
Thiram	96	HHBP	Chronic, General Population	21	ALB	Fish, Acute	
Triadimefon	220	HHBP	Chronic, General Population	41	ALB	Fish, Chronic	
Triadimenol	22	HHBP	Chronic, General Population	--			
Triallate	0.446	HHBP	Cancer	14	ALB	Invertebrates, Chronic	
Tribenuron-methyl	50	HHBP	Chronic, General Population	2	ALB	Non-Vascular Plant	
Triclopyr, butoxyethyl ester	--						
Triclopyr, Triethlamine salt	300	HHBP	Chronic, General Population	5900	ALB	Non-Vascular Plant	
Trifloxystrobin	240	HHBP	Chronic, General Population	2.76	ALB	Invertebrates, Chronic	
Triflumizole	74.9	HHBP	Chronic, General Population	33	ALB	Fish, Chronic	
Trifluralin	4	HA	Cancer	1.9	ALB	Fish, Chronic	
Triflusulfuron-methyl	156	HHBP	Chronic, General Population	--			
Trinexapac-Ethyl	2000	HHBP	Chronic, General Population	190	ALB	Non-Vascular Plant	
Triticonazole	1100	HHBP	Chronic, General Population	--			
Uniconazole-P	100	HHBP	Chronic, General Population	--			
Urea dihydrogen sulfate	--						
Zinc phosphide	0.6	HHBP	Chronic, General Population	--			
Zinc sulfate	Metals/Salts Excluded						
Ziram	34	HHBP	Chronic, General Population	4.85	ALB	Fish, Acute	
Zoxamide	3100	HHBP	Chronic, General Population	3.48	ALB	Fish, Chronic	
Other Pesticides and Degradates of High Interest for Drinking Water							
1,2,4-Triazole	30	HHBP	Chronic, General Population	--			
2,6-Dichlorobenzamide (BAM)	29	HHBP	Chronic, General Population	10000	ALB	Fish, Chronic	
Bensulfuron methyl	1000	HHBP	Chronic, General Population	--			
Bispyrabac Sodium	600	HHBP	Chronic, General Population	12	ALB	Non-Vascular Plant	
Carbendazim (MBC)	13.4	HHBP	Cancer	0.99	ALB	Fish, Chronic	
Clomazone	5400	HHBP	Chronic, General Population	167	ALB	Vascular Plant	
Cyhalofop-butyl	60	HHBP	Chronic, General Population	47.4	ALB	Invertebrates, Chronic	
Methyliosthiocyanate (MITC)	190	AAL		25	ALB	Invertebrates, Chronic	
Orthosulfamuron	300	HHBP	Chronic, General Population	0.7	ALB	Non-Vascular Plant	
Propanil	60	HHBP	Chronic, General Population	9.1	ALB	Fish, Chronic	
Thiobencarb	1	CA Secondary MCL		1	ALB	Invertebrates, Chronic	CA Primary MCL = 70
Triazole Acetic Acid	30	HHBP	Chronic, General Population	--			
Triazole alanine	30	HHBP	Chronic, General Population	--			

Yellow Shading - highlights lowest reference value for each chemical (only for chemicals with a human health reference value)
Where multiple reference values exist, the lowest reference value was selected for each category
Analysis excludes metals and salts
Cancer - used 10-6 risk to be consistent with California law and regulations (e.g., Proposition 65)
"--" means no reference value was identified

Reference Values Reviewed:
US EPA Human Health Benchmarks for Pesticides = HHBP
US EPA Aquatic Life Benchmarks for Pesticides = ALB
US EPA Drinking Water Standards and Health Advisories
  Maximum Contaminant Level = US EPA MCL
  Health Advisory = HA
California Drinking Water Regulatory Levels
  CA Maximum Contaminant Level = CA MCL
  AAL = Archived Advisory Level
  NL = CA Notification Level
US EPA-Established California Water Quality Standards
  US EPA California Toxics Rule = US EPA CTR
US EPA National Recommended Water Quality Criteria = US EPA NRWQC
  Criterion continuous concentration = CCC
  Criterion maximum concentration = CMC
  Fresh Water = FW
  Salt Water = SW
Public Health Goals are not included in this analysis.