



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

OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

MEMORANDUM

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SUBJECT: Assessment of Drinking Water Exposure and Acrolein Concentrations to which Fish May Be Exposed, 2nd revision (for error correction comments)
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Executive Summary

This memo dates the revises the previous drinking water memo for error correction comments received from the registrant, Baker Petrolite in Phase 1 of the reregistration process. It includes a review and discussion of two monitoring studies that were submitted as Magnitude of Residue studies for potable water studies and were previously reviewed by HED (D164239, D169594) and an assessment of potential exposure to humans from the consumption of fish that may be contaminated with acrolein. Potential exposures to acrolein through drinking water are qualitatively described as well. This document was prepared in support of the reregistration eligibility decision for that compound. Information from registrant-submitted and open-literature environmental fate studies, as well as, from monitoring studies in irrigation systems have been used for this assessment.

Acrolein has two use patterns: as an herbicide for control of vegetation in irrigation canals and as a biocide in water pumped into injection wells associated with petroleum production. The latter appears to be used only as a closed system with exposure that would not impact surface or ground water used for drinking water, and will not be further discussed here. For herbicidal use in irrigation canals, the maximum single application concentration of acrolein is 15 ppm. This application rate is used when there is high weed density in the treated canal. Applications can occur multiple times during a year; neither the maximum number of applications, nor the minimum interval between applications is specified on the label. Based on application data provided by the registrant, Baker Petrolite Corporation (MRID 46976913), applications are made to irrigation systems in 15 states in the Great Plains or West: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. The maximum single application rate used during the year at each irrigation system is most often 8 ppm but applications at 15 ppm commonly occur (reported in at least one irrigation district in 9 of 15 of these states). Acrolein is applied up to 20 times per year in some irrigation systems with an interval as short as 7 days, but 6 applications per year is the most common, with a two or three week interval between applications. In some irrigation systems applications are more frequent but at lower concentrations required to control the lower weed density (some users refer to this as “chemical mowing”¹). More typically, (Baker Petrolite Corporation; MRID 46976913), applications are made two or three times a year. Reported treatment durations ranged from 1 to 12 hours with 4 hours being the most common duration.

Based on the limited available laboratory fate data, and the available field study and monitoring study data, while it appears that acrolein dissipates from irrigation canals with a half-life of less than one day, it is sufficiently persistent and mobile that it may reach the drainage points of irrigations systems in concentrations frequently between 0.1 and 1 ppm and at distances up to 70 miles from the application point. This indicates that if water containing acrolein reaches the terminus of an irrigation system, and cannot be held back by containment or diversion structures, acrolein will enter natural waters. The concentrations at a drinking water facility downstream from a discharging irrigation system would depend upon the dilution due to the relative flow rates of the irrigation system (or volumes in the case of reservoirs) and of the receiving water body, and the travel time between the two points. Some reduction in acrolein concentration would be expected during the drinking water treatment process, as some volatilization would likely occur during treatment, but the magnitude of the reduction cannot be quantified. Air stripping is a particular drinking water treatment technology that can remove volatile compounds, but a preliminary assessment based on the Henry’s Law Constant indicates that standard air stripping would not completely remove acrolein from drinking water. It is possible that an air stripping system could be specifically designed for that purpose.

Acrolein forms 3-hydroxypropanal spontaneously in solution, but it is an equilibrium process and acrolein will be reformed from 3-hydroxypropanal as acrolein is dissipated by other processes. Other degradates (mostly 3-carbon acids and alcohols) are formed by microbial metabolism. These compounds are listed in Table 1. In two potable water studies, 3-hydroxypropanal was found at concentrations 10% of the apparent acrolein application rate at concentrations over 2000 $\mu\text{g}\cdot\text{L}^{-1}$ and at up to 30 h after the beginning of application to the water body.

¹ Personal communication, Hugh MacEachen, Columbia Basin Irrigation District, January 2007

Fate and Transport Characterization

The environmental fate of acrolein, or 2-propenal, is not well described based on current environmental fate data. Available data indicate potential for acrolein to reach surface-water source drinking water. Volatilization, microbial metabolism, and possibly binding into plant material, are potential major routes of dissipation but it is not clear which of these routes may dominate in the environment and under what conditions.

No data are currently available to substantiate that binding into the plant material could be a route of dissipation for acrolein. However, acrolein's pesticidal mode of action involves cross-linking biological macromolecules, through interaction with sulfhydryl groups (Ghilarducci and Tjeerdema, 1995), *i.e.* the amino acid cysteine in proteins, and may also interact with nucleic acids. This cross-linking should 'use up' the acrolein as it kills plants and algae in the irrigation canal. This notion is at least somewhat supported in that the label recommends higher use rates for greater weed densities in the treated canals. At this time, however, the nature and extent of this route is highly uncertain and speculative in nature.

Acrolein is a highly reactive molecule. It must be stabilized with hydroquinone, or it will exothermically self-polymerize in the presence of air and ultra-violet light, or temperatures higher than 150°C (Ghilarducci and Tjeerdema, 1985). Acrolein is a liquid at 25 °C but has a vapor pressure of 0.354 atm at the same temperature (Smith 1962), and will rapidly volatilize if not kept in a closed container (Ghilarducci and Tjeerdema, 1985). Acrolein is also very soluble in water, at 237.6 g/L at 25°C (MRID 40840602). This high solubility tends to mitigate the volatilization tendency somewhat, as indicated by the measured Henry's constant of $1.9 \times 10^{-4} \text{ atm}\cdot\text{m}^3\text{mol}^{-1}$ (MRID 47008401; Salma, 2001; Smith, 1962).

Acrolein does not follow ideal behavior, as the measured partial pressures are about twice what would be predicted from Raoult's Law. The Henry's Law constant (K_{Hen}) varies according to temperature according to the Equation 1 where t is temperature in degrees Celsius. This suggests that acrolein may be undergoing a reversible dimerization reaction in aqueous solution. Acrolein does form a dimer through the addition of one acrolein across the double bond of a second forming 3,4-dihydro-2H-pyran-2-carboxaldehyde.

$$\text{Eq.1 } K_{\text{Hen}} = 5.561 - 781(177 - t)$$

Following are brief descriptions of the available fate data and some of the available monitoring data which describe acrolein occurrence in the environment.

Hydrolysis. Acceptable data are available to characterize the hydrolysis of acrolein. Acrolein does not undergo hydrolytic degradation in aqueous solution, but rather goes into equilibrium with a hydration production, 3-hydroxypropanal, where water has added to the double bond (MRID 40945401). At 25°C, the equilibrium constant for this reaction is 10.4 ± 5.7 and appears to be independent of pH. The observed rate of reaction varies with pH, with half-lives of 92, 37, and 19 hours at pH values of 5.28, 7.19 and 8.92, respectively. Because the rate of reaction does not vary directly with the hydrogen ion concentration, it suggests that the hydration reaction proceeds by more than one mechanism. In natural waters, rates appear to be about an order of magnitude faster than in pure water indicating there are components in the natural water that catalyze the reaction.

Photolysis. No currently acceptable data are available to characterize the rate of photolysis for acrolein in water. This is a significant data gap in our understanding of the environmental fate properties of acrolein.

Microbial Metabolism. Submitted data provide evidence that acrolein does indeed degrade by both aerobic and anaerobic metabolism. However, available studies were not sufficient to quantify degradation rates, although the parent has an observed DT₅₀ of about a day. Both an aerobic aquatic (MRID 42837601) and anaerobic aquatic metabolism study (MRID 42949201) had evidence of both oxidation and reduction processes occurring in the test systems as both oxidative and reductive degradates were produced. Degradates formed by oxidation include acrylic acid, propionic acid, oxalic acid and carbon dioxide. Allyl alcohol, a reduction product, was also seen in both studies. Both reduction and oxidation products can occur in these test systems as there is a redox gradient between the water column and the bottom sediment, with the water column generally being relatively more oxidized than the bottom sediment. The abiotic degradate 3-hydroxypropanal was identified as a minor degradate, as well as 3-hydroxypropionic acid, which probably formed by oxidation of the aldehyde. Table 1 lists the degradates and the maximum percentage of the nominal parent concentrations by study type.

Table 1. Maximum percentage of the nominal concentration of degradates formed from acrolein by abiotic and metabolic degradation processes. The time after experiment initiation that maximum occurred is in parentheses.

Degradate	Hydrolysis	Aerobic Aquatic Metabolism	Anaerobic Aquatic Metabolism
Acrylic acid	--	19% (2 d)	38.0% (1 d)
Allyl alcohol	--	8% (0 d)	16.7% (1 d)
Propionic acid	--	20% (2 d)	63.5% (8 d)
Oxalic acid	--	2% (2 d)	49.3% (30 d)
Bicarbonate	--	39% (5 d)	89.3% (30 d)
3-hydroxypropanal	90.9% (all pH's)*	--	7.2% (1 d)
3-hydroxypropionic acid	--	9% (2 d)	3.6% (1 d)
Propanol	--	21% (1 d)	9.2% (1 d)
Glyceric acid	--	1% (5 d)	--

* estimated concentration at equilibrium

Adsorption/Desorption. No acceptable data are available for estimating K_d values for acrolein. Qualitative information can be used from the metabolism studies and chemical properties of acrolein to identify the potential adsorption/desorption of acrolein. In the aerobic and anaerobic aquatic metabolism studies cited above, acrolein was not identified in the sediment of the test vessels. This suggests that acrolein does not partition into sediment to any significant extent. In addition, the very high solubility (237 g/L at 25°C) would indicate a very low tendency to absorb to sediment.

Magnicide Monitoring Program for the State of Nebraska (MRID 46976905). This study was conducted in 8 canals in five irrigation districts in Nebraska in 1982. Chemical analysis was made both with the colorimetric dinitrophenylhydrazine (DNPH) and a polarographic procedure. Applications of between 0.5 and 5 ppm of acrolein were made to irrigation canals and the pesticide was monitored downstream to the discharge point from the irrigation canal.

Dissipation half-lives were estimated for this study based on the peak concentration in the plume as it moved downstream, by identifying the maximum concentration measured at each site, and noting the time after the start of application that this concentration occurred. The DT₅₀ was

then estimated from these values using linear regression on log-transformed data and assuming a first-order dissipation model. In some cases, two applications were made to the canal with the second application made downstream of the first application. For some irrigation systems, this made it difficult to interpret the data because the pulses from the two applications overlapped to some extent. Half-lives were estimated for seven of the eight canals and ranged from 2 to 9.8 h.

In five of the eight canals, acrolein was found in measurable concentrations just upstream from the discharge of the irrigation system. In the 2832 lateral of the Farmer’s Irrigation District, the concentration of acrolein near the discharge from the canal was 1150 ppb and was diluted to 20 ppb in the receiving water body, the Nine Mile Canal. In the Meeker Canals of the Frenchman-Cambridge Irrigation District, acrolein was found at 230 ppb at 27 h after application and after traveling 31 mi. In the Red Willow Canal of the Frenchman-Cambridge Irrigation District, the drain discharges to a dry creek which is a tributary to the Republican River. Discharge from the canal, containing up to 410 ppb of acrolein could potentially then travel undiluted to the river, although no measurements were made beyond the discharge point from the canal (Table 2).

In a companion study, reported with the Nebraska monitoring data, acrolein dissipated below the detection limit of 10 ppb during transit across a 0.15 mi long irrigation ditch in a bean field. As a result of this study, the registrant recommended diversion of irrigation water into holding ponds or onto irrigated crops to avoid discharge of irrigation water containing acrolein. Note that state “Do not use where waters will flow into potential sources of drinking water. Water treated with Magnacide H Herbicide must be used for irrigation of fields, either crop bearing, fallow or pasture, where treated water remains on the field OR held for 6 days (2 days for some SLNs) before being released into fish bearing waters or where it will drain into them.”

Table 2. Acrolein movement in Nebraska irrigation canals. Canals marked with an asterisk had detectable concentrations at the drainage point from the canal.

Irrigation Canal	Nominal Application Concentration (ppb)	Time for last Detection (hours)	Furthest Distance from Application Site (mi)	Concentration at Furthest Distance Site (ppb)	Dissipation Half-life† (hours)
Red Willow*	2400	23	15	410	9.8
Meeker*	2400	27	31	230	**
Franklin Main	1900	12	16	700	2.8
Farwell*	4000	27	11	310	6.6
Bone Lateral	500	8	7.3	170	3.9
Airport Lateral	500	7	6.2	34	2.0
2165 Lateral*	3200	8	6.5	54	3.8
2832 Lateral*	4900	5	3	1150	5.2

* Sites marked with an asterisk had acrolein measured at the discharge point of the irrigation canal.
 ** Dissipation occurred but rate half-life could not be estimated.

Washington State Monitoring Program (MRID 47008404). The primary purpose of this study was “to provide data to substantiate the viability of a lower, more realistic holding restriction for treated water in the state of Washington.” The study was conducted from June 24, to July 10, 1986. Seven applications were made to four canals, East Low Canal, Potholes East Canal, Roza Main Canal, and Town Ditch Canal with a similar protocol to that used for the Nebraska study (MRID 46976905). Of the seven applications to these four sites, four could be resolved into separate plumes traveling downstream. A dissipation half-life could not be calculated from one of these four because of an unspecified volume of dilution from irrigation return flow entering the canal between the application

zone and the irrigation canal discharge. Application rates ranged from 1 to 3 ppm. When dissipation half-lives could be estimated, they were in general, somewhat longer than in Nebraska but still less than 1 d, ranging from 12 to 19 h (Table 3). In all cases measurable concentrations of acrolein were found in the discharge from the canal.

Acrolein was found in the Scootenay Wasteway at 50 ppb, one-half mile below the end of the East Low Canal and 61 miles from the application site, but had dissipated below the detection limit 3.5 mi downstream before discharging into the Scootenay Reservoir. Water containing acrolein from the Potholes East Canal containing 0.36 ppb acrolein was found in a stilling pond at 0.28 ppb after first passing through the P.E.C. 66 Power Plant. It was not, however, found in the Columbia River, 100 ft downstream from the pond. The Roza Main Canal had different discharge points for the first and second applications (Coral Creek, 22.8 mi downstream from application site) and third applications (Sulphur Creek, 17.8 mi downstream from application site). Both of these creeks were monitored just above their confluence with the Yakima River, and neither case was there detectable acrolein. The Town Ditch drains into the Badger Wasteway which was monitored 0.5 mi from the where Town Ditch enters, and also had no detectable acrolein.

In a companion study, irrigation water from the East Low Canal containing 1.2 ppm acrolein was diverted down a 0.2 mi long furrow. The acrolein concentration decreased to 0.25 ppb at the end of the furrow. Irrigation water at the same concentration from the Potholes East Canals diverted through a furrow in an onion field dropped to 0.52 ppb after traveling 0.1 miles down the furrow. Baker Performance Chemicals concluded that “if irrigation districts are unable to pond treated water for the required holding time, then diverting the wave of treated water onto irrigated crops near the wasteways can be viewed as a reasonable alternative. If no weed or algae control is desired near the wasteway, the districts can also move their applications further upstream in the canals.”

Table 3. Acrolein movement in Washington irrigation canals. Canals marked with an asterisk had detectable concentrations at the drainage point from the canal.

Irrigation Canal	Nominal Application Concentration (ppb)	Time for last Detection (h)	Furthest Distance from Application Site (mi)	Concentration at Furthest Distance Site (ppb)	Dissipation Half-life (h)
East Low*	1500	23	61	50 †	19.9
Potholes East, 1 st application*	1500	26	35	410 ††	12.2
Potholes East, 2 nd application*	1600	5	21	280 ††	**
Roza Main, app 1 *	770	27	64	80	13.6
Roza Main, app 2*	980	24	23	80	***
Roza Main, app 3 *	990	7	18	160	**
Town Ditch*	3000	26	20	20	‡

*Sites marked with an asterisk had acrolein measured at the discharge point of the irrigation canal
 ** Dissipation occurred but rate half-life could be estimated from data set.
 *** Application overlapped 1st application, and dissipation rate could not be estimated
 † Concentration is the receiving water body just past the discharge from the canal.
 †† Last measured values was in a stilling pond 1 mi downstream from the discharge of the canal into the PEC 66 Power Plant, just above the Columbia River.

‡ Dissipation estimate could not be made due to dilution from incoming return flow

Washington Department of Agriculture, 2004. Data were provided to OPP by Washington State Department of Agriculture for 2004 NPDES monitoring of applications of acrolein to irrigation canals in 3 irrigation districts in the state. Ancillary data on application locations and collection and analytical methods have been received but could not be reviewed in time to be considered in this document. Consequently, these data only provide supplemental information on the occurrence of acrolein in irrigation systems; however, these monitoring data are useful for characterizing applications of acrolein to irrigation canals in Washington State (Table 4). Samples were taken at the point of compliance (POC) which is a sampling point near but not necessarily at the point of discharge from the canal. The POC is the location at which sampling is done for NPDES permit compliance sampling (compliance with the Clean Water Act, not the Federal Insecticide Fungicide and Rodenticide Act) and “are at ‘natural waters’ where surface water courses existed prior to the alteration of water drainage and creation of reclamation and irrigation projects (State of Washington, Department of Ecology, 2002). In practice, the POC may be some distance upstream from the actual drainage point because of constraints of accessibility.² Sampling data that were provided indicate that many of the application events in 2004 resulted in non-detections of acrolein at the POC (data not shown); however, at locations where detections did occur at the POC, acrolein was detected at levels exceeding the state’s NPDES permit level of 21 ppb. The data indicate that acrolein moved many miles (>65 miles) downstream in irrigation canals and still exceed 21 ppb for periods of time greater than 48 hours after upstream applications of acrolein. For applications of acrolein in Washington State, a 48 hour holding period is required for treated waters before reaching receiving water bodies outside the irrigation system.

Kern County Water Storage District (MRID 47008403). Irrigation water containing the full treatment rate of acrolein was used to irrigate two fields: a vineyard (by furrow irrigation) and an alfalfa field (by flood irrigation). Samples were analyzed for acrolein using the Differential Pulse Polarography (DPP) method which can distinguish acrolein from 3-hydroxypropanal. An initial concentration of 10.8 ppm in the vineyard had dissipated below the detection limit 600 ft down the furrow, 2 hrs after application. In the alfalfa field, an initial mean concentration of 4.0 ppm was below the detection limit 400 ft away from the application point about 2 hrs after the termination of application. The detection limit was reported as 10 ppb; however, no values less than 100 ppb are reported in study and the lowest calibration standard was 1 ppm, so the reported detection limit in this study is questionable. The authors’ conclusion was “The above data supports the premise that irrigating dry fields is a viable means of dissipating Magnacide H when it is not possible to contain the treated water within the system for six days.”

² Personal communication, Wendy Sue Wheeler, Washington State, Department of Ecology, December, 2005.

Table 4. Occurrence of acrolein at the point of application (POA) and the point of compliance (POC) of irrigation systems sampled by the Washington Department of Agriculture.

Description of Location	Acrolein conc. (ppb) at POA	Distance between POA and POC (miles)	Duration of Application (hours)	Time between app. and sampling at POC (h)	Acrolein Conc. (ppb) at POC
Quincy (3 Gates)	650	64.3	8	53	1.0
South (Esquatzel Wasteway)	2600	13.6	6	14	1.0
South (Wahluke Branch 5 Wasteway 1)	3900	14.8	4	23	1.1
Quincy (5th Section Canal)	790	68.1	8	53	1.5
Quincy (5th Section Canal)	2850	26.1	1.8	54	1.5
South (Esquatzel Wasteway)	2600	7.0	3	9	2.2
Quincy (78-8)	790	67.1	8	56	2.4
Quincy (78-8)	2620	24.6	6	33	2.4
Quincy (3 Gates)	790	64.3	8	52.9	2.9
South (Potholes East 16.4 Wasteway)	5200	12.8	3	31	3.1
South (Esquatzel Wasteway)	2600	7.0	3	11	5.6
Quincy (78-8)	790	67.1	8	53	8.3
South (Potholes East 16.4 Wasteway)	3600	19.6	4	24	9.3
South (Wahluke Branch 5 Wasteway 1)	3900	7.7	4	13	12.1
South (Esquatzel Wasteway)	2600	2.6	3	18	14.6
South (Esquatzel Wasteway)	2600	2.6	3	20	15.0
Quincy (5th Section Canal)	2620	26.1	3	10	21.7
Quincy (5th Section Canal)	790	68.1	8	56	23.2
Quincy (W61L lateral)	790	66.1	8	52	23.5
Quincy (Farm Unit 88)	2620	17.9	6	26	29.2
South (Potholes East 16.4 Wasteway)	3600	19.6	4	26	36.1
South (Wahluke Branch 5 Wasteway 1)	3900	7.7	4	15	62.5
Quincy (5th Section Canal)	650	68.1	8	54	67.2
Quincy (3 Gates)	2620	14.9	3	16	117
South (Wahluke Branch 5 Wasteway 1)	5200	9.1	3	18	225
South (Wahluke Branch 5 Wasteway 1)	5200	13.4	3	23	254

Potable Water Monitoring Study – Arizona Site (MRID 41855401). This study was conducted in order to fulfill the data requirement for Magnitude of Residue in Potable Water (171-4), which is required for aquatic food and non-food use crops. This study was previously reviewed and found to be acceptable for regulatory use (D169594). While the stated purpose of this study differs from those described above, the conduct of the study was in fact nearly identical, other than the concentrations

of 3-hydroxypropanal were reported as well as parent acrolein. The Main Canal in the Roosevelt Irrigation District was treated with a nominal rate 15 mg L^{-1} of acrolein and then monitored at nine sites along the 29 mi canal. The last site was 27.2 mi from the application point and not at the discharge point from the canal. The nominal application rate was in fact exceeded and the maximum concentration detected in the canal at the first monitoring site 0.28 mi downstream (Table 5) from the application site was 20.2 mg L^{-1} . Substantial concentrations of acrolein ($1600 \text{ } \mu\text{g L}^{-1}$) were still being found in the canal at the last monitoring point 30 h after application. 3-hydroxypropanal was found starting at the 4th site downstream, 8 mi from the application site and 7 h after application. The highest concentration $2900 \text{ } \mu\text{g L}^{-1}$ was found at 19 mi from the application site, 18 h after application and decreased somewhat downstream, but was still being found at $2.4 \text{ } \mu\text{g L}^{-1}$, 27 mi downstream 29 h after application. At this point the 3-hydroxypropanal concentrations were higher than the parent which $1.6 \text{ } \mu\text{g L}^{-1}$ at the same site and time.

Table 5. Acrolein movement in potable water studies in Arizona and Washington (41855401, 41933001).

Irrigation Canal	Time for last Detection (h)	Furthest Detect from Application Site (mi)	Maximum 3-hydroxypropane Concentration (ppb) (distance in parentheses)	Concentration at Furthest Distance Site ($\mu\text{g L}^{-1}$)	Dissipation Half-life (h)
Roosevelt Main Canal, AZ	30	27.2	2.9 (19.4)	1600	11.6
Wapato Pump Canal, WA	34	19.5	0.60 (17 mi)	1700	12.9
Wapato lateral, WA	9	3	0.32 (3 mi)	5200	7.9

Potable Drinking Water Study – Washington (41933001). As with the above study, this one was conducted in order to fulfill the guideline requirement for the magnitude of residues in potable water, and as with that study, it is essentially a LaGrangian study that tracks the “pulse” of acrolein as it moves down the length of the irrigation canal. This study was conducted in the Wapato Irrigation District in Washington State. Two canals were treated, the pump canal, and a lateral, with lengths of 19.5 and 3 mi, respectively. There were six monitoring sites along the lateral canal and nine monitoring sites along the pump canal. As with the Arizona potable water study, the nominal concentration for application was 15 mg L^{-1} , but the measured concentration at the first site exceeded the nominal in the pump canal with 19 mg L^{-1} at the first monitoring site 0.1 mi downstream (Table 5). The highest measured concentration in the lateral canal was at the second monitoring site which 0.85 mi downstream from the application site and was 10 mg L^{-1} . Acrolein was detected at the last monitoring site on both canals with $5200 \text{ } \mu\text{g L}^{-1}$ in the later and $1700 \text{ } \mu\text{g L}^{-1}$ in the pump canal. Dissipation half-lives in these two water bodies were in the same range as those in the other monitoring studies, at 7.9 h and 12.9 h in the later and pump canals respectively.

3-hydroxypropanal was found in both canals. In the pump canal, it was found starting at the fifth monitoring site, 4.5 h after application and 3 mi downstream at $310 \text{ } \mu\text{g L}^{-1}$. It was found at all subsequent sites with a peak concentration of $600 \text{ } \mu\text{g L}^{-1}$ 15 mi downstream and 22 h after application. In the lateral canal, 3-hydroxypropanal was found only at the last two sites, starting at 2.65 mi downstream and 6.5 h after application at $230 \text{ } \mu\text{g L}^{-1}$. The maximum concentration was at the last site (3 mi) at $320 \text{ } \mu\text{g L}^{-1}$.

Drinking Water Treatment

There is currently no Maximum Contaminant Level set for the protection of drinking water for acrolein under the Safe Drinking Water Act. There are no direct studies indicating how drinking water treatment would impact acrolein during drinking water treatment if acrolein reaches the intake for a drinking water facility. It would be expected that volatilization would play a major role in dissipating acrolein from drinking water during treatment since aeration plays a significant role in several steps during treatment; however, it is unlikely to completely remove it. Air stripping is a method for removing volatile compounds from water (OPP, 2001). Based on a study by McCarty (1987), compounds with a Henry's Law Constant of $1 \times 10^{-3} \text{ atm}\cdot\text{m}^3/\text{mol}$ were amenable to remediation by air stripping. While acrolein is very volatile, it also very soluble, so the Henry's Law Constant, which is related to both properties, is only $1.92 \times 10^{-4} \text{ atm}\cdot\text{m}^3/\text{mol}$, indicating that it may not be completely removed by air stripping unless stripping towers were specifically designed for that purpose (OPP, 2001).

Acrolein Concentrations to which Fish May Be Exposed

It is possible that there is exposure to acrolein or its metabolites through the consumption of fish which live in irrigation canals, or waters which receive drainage from treated canals. In order to assess this exposure, it necessary to identify the concentrations of acrolein in which fish are living. These concentrations can then be used to estimate the body load of acrolein and its metabolites in consumed fish. Concentration ranges in canal can be as high as the application rate and concentrations over $1000 \mu\text{g}\cdot\text{L}^{-1}$ have measured at the discharge points from canals, as discussed above. If these canals discharge in rivers or streams during summer low-flow conditions, concentrations in the receiving water body could potentially be similar to those in the canal. However, fish are not likely to persist in an edible state in these concentrations. Since only living fish can be caught by angling, acute fish toxicity data can indicate what are the highest concentrations which are tolerated by fish, and hence the highest concentrations to which consumed fish may be exposed. Median lethal concentrations for fish species are tabulated in Table 6. These values range from $14 \mu\text{g}\cdot\text{L}^{-1}$ for fathead minnow to $69 \mu\text{g}\cdot\text{L}^{-1}$ for coho salmon. The latter would serve as a good estimate of the maximum concentration to which fish may exposed and still be caught as about half the fish will survive this concentration and coho salmon are commonly eaten fish species.

Table 6. Summary of submitted acute toxicity data for fish exposed to acrolein. ECOTOX literature search identified data which are more conservative than registrant submitted data. These data are also included in this table. Additional acute toxicity data are available; however, data which were greater than submitted data (or data with MRID numbers) were not included in this table.

Species (common name)	Measure of Effect	End-point	Duration (hours)	Mean concentration, units in µg a.i./L (95% c.i.)	Test substance (% a.i.)	Study Classification	Ref. (MRID)
Freshwater Fish and Amphibians							
<i>Pimephales promelas</i> (fathead minnow)	Mortality	LC ₅₀	96	14 (8-25)	N/A	Supplemental	Holcombe <i>et al.</i> 1987*
<i>Pimephales promelas</i> (fathead minnow)	Mortality	LC ₅₀	96	14	97		Geiger <i>et al.</i> 1990*
<i>Catostomus commersoni</i> (white sucker)	Mortality	LC ₅₀	96	14 (8-25)	N/A	Supplemental	Holcombe <i>et al.</i> 1987*
<i>Oncorhynchus mykiss</i> (rainbow trout)	Mortality	LC ₅₀	96	16 (14-19)	N/A	Supplemental	Holcombe <i>et al.</i> 1987*
<i>Pimephales promelas</i> (fathead minnow)	Mortality	LC ₅₀	96	19.5 (17.3-22.0)	>99	N/A	Geiger <i>et al.</i> 1988*
<i>Lepomis macrochirus</i> (Bluegill Sunfish)	Mortality	LC ₅₀	96	22.4 (20.2-24.8)	96.4	Supplemental	415132-01
<i>Oncorhynchus mykiss</i> (rainbow trout)	Mortality	LC ₅₀	96	<31	96.4	Supplemental	415132-03
<i>Oncorhynchus kisutch</i> (Coho salmon)	Mortality	LC ₅₀	96	68	N/A	N/A	452051-07

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