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OFFICE OF
PREVENTION, PESTICIDES AND
TOXIC SUBSTANCES

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MEMORANDUM

Subject: Malathion use as a mosquitocide and potential risk to listed salmonids

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Summary

Two types of exposure assessments were conducted for malathion used to control larval mosquitoes and adult mosquitoes resting on vegetation. The labels and uses evaluated were those identified by the Endangered Species Protection Program (ESPP) in the request for this assessment. The mosquito labels identified by the ESPP were not included in the Environmental Fate and Effects Division (EFED) ecological risk assessment for malathion (http://www.epa.gov/oppsrrd1/op/malathion/efedrra.pdf) because EFED was informed that the registrant for malathion (Cheminova) did not intend to support uses allowing direct application of malathion to water bodies except for use on rice and waste water treatment. The risks calculated in this assessment for salmonids and their invertebrate prey items are relatively high-end estimates representing vulnerable environmental sites and application conditions which result in relatively high exposures. Exposure values are used to calculated risk quotients (RQs) which are compared to the acute listed species level of concern (LOC) for direct effects to salmonids (0.05) and the acute LOC for indirect effects via effects to non-obligate invertebrate food items (0.5). An exceedance of an LOC indicates the potential of an effect to the listed

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salmonids. No data were provided for malathion's toxicity to plants but malathion's use as an insecticide and malathion's mode of action in animals (the nervous system) suggests that plants are not likely to be affected.

The two assessment scenarios evaluated were intended to represent a vulnerable static aquatic environment (*e.g.* a lake or estuarine area) and a vulnerable flowing water body (*e.g.* a small stream).

The Environmental Fate and Effects Division's (EFED's) interim rice model (10/29/2002 policy) was used in conjunction with the measured aquatic half life for malathion to estimate concentrations in a static surface water body. The peak estimated concentration results in risk quotients that exceed the direct and indirect LOCs. Using aquatic half life data for malathion the LOC would be expected to be exceeded for over 30 days. This scenario considers partitioning of malathion to sediment and degradation but is considered to be conservative in that it represents direct application to a 4 inch deep water body and no dilution from other water sources. Deeper water and the addition of more water would result in lower concentrations and lower risk levels; the depth required to reduce risk quotients below LOCs is >330 feet.

The stream module of the AGDISP model was used to estimate concentrations in flowing water bodies and resulting direct and indirect risks to listed salmonids. Using application conditions simulating an aerial application treating streamside vegetation, the estimated aquatic concentration, adjusted for 96 hours of exposure, resulted in risk quotients exceeding the LOCs for direct and indirect effects. The exposure scenario used in the stream assessment is considered to be conservative in that 1 mile of streamside vegetation is assumed to be treated while the wind is blowing into the water. The depth of the water and lack of dilution also contribute to the conservatism of the assessment. A flowing water body that is 150 or more feet deep would not be expected to result in an exceedance of the LOCs.

Results are summarized in Table 1 below.

Type of water body	Direct Effect RQ / LOC	Duration that RQ exceeds LOC	Indirect Effect RQ / LOC	Duration that RQ exceeds LOC
Static	15.3 / 0.05	13 days	443 / 0.5	32 days
Flowing	1.3 / 0.05	< 1 hour	44.4 / 0.5	< 1 hour

Toxicity Data

Mayer and Ellersieck (1986) provide a source of toxicity data for multiple salmonid species over 24 to 96 hour exposure periods. The LC50 for 96 hours of exposure is the standard toxicity value used to generate risk quotients and is used in this assessment for the static water body assessment. Toxicity data associated with shorter exposure durations, however, are more appropriate in this instance for the stream assessment.

Table 2. Malathion Toxicity to Salmonid Species (Mayer and Ellersieck 1986) (most sensitive values are shaded)				
Species	No. tests	Mean 24 hour LC50 (μg/L)	Mean 96 hour LC50 (μg/L)	24 hr LC50: 96 hr LC50 ratio
Coho salmon	2	327	174	1.88
Cutthroat salmon	4	388	239	1.63
Rainbow trout	7	142	97	1.45
Brown trout	1	128	101	1.27
Lake trout	2	139	109	1.28

Mayer and Ellersieck also list 24 and 96 hour toxicity data for other species. The EFED environmental risk assessment identified a bluegill sunfish LC50 value (30 ppb) as most appropriate for malathion's major use areas. A lower 96-hour LC50 for bluegill, 20 ppb, is presented in Mayer and Ellersieck (1986). This value, along with the related 24-hour LC50 of 90 ppb, was used as a protective toxicity value for salmonids in this assessment.

Toxicity data for aquatic invertebrates from Mayer and Ellersieck (1986) are presented in Table 3. The EFED risk assessment used an acute exposure EC50 for daphnids of 1 ppb. Mayer and Ellersieck (1986) presents slightly lower values. The toxicty values for aquatic invertebrates used in this assessment corresponded to the lowest values cited in Mayer and Ellersieck (1986): 0.69 ppb and 2.7 ppb for Gammarus and Isperla, respectively.

Table 3. Malathion Toxicity to Aquatic Invertebrate Species (Mayer and Ellersieck 1986) (most sensitive values are shaded)				
Species	No. tests	Mean 24 hour LC50 (μg/L)	Mean 96 hour LC50 (μg/L)	24 hr LC50: 96 hr LC50 ratio
Atherix variegata	1	1450	385	3.77
Asellus brevicaudis	1	6000	300	20.0
Gammarus fasciatus	3	2.7	0.72	3.75
Orconectes nais	1	290	180	1.61
Palaemonetes kadiakensis	2	235	51	4.61
Claassenia sabulosa	1	13	2.8	4.64
Isoperla sp.	1	4.6	0.69	6.67
Pteronarcella badia	1	10	1.1	9.09
Pteronarcys californica	1	35	10	3.5
Lestes congener	1	27	10	2.7
Limnephilus sp.	1	6.8	1.3	5.23

Static Water - Interim Rice Model

In the rice model, estimated environmental concentrations (EECs) are estimated by diluting the application into the paddy and partitioning the pesticide between the water and the paddy sediment according to a linear K_d partitioning model. The EEC ($\mu g.\ L^{-1}$) represents the dissolved concentration occurring in the water column and the concentration in water released from the paddy into adjacent surface water. In this instance the paddy is used to represent a shallow lake or estuarine area. Movement of pesticide on suspended sediment is not considered. The equation to use for this calculation is:

$$EEC = \frac{10^9 M_T}{V_T + m_{sed} K_d}$$

where M_T is the total mass of pesticide in kg applied per ha of paddy, V_T is 1.067×10^6 L ha^{-1} which is the volume of water in a paddy 4 inches (10.16 cm) deep, and includes the pore space in a 1 cm sediment interaction zone. The mass of sediment, m_{sed}, is the amount found in the top 1 cm interaction zone and is 130,000 kg ha^{-1} when the sediment bulk density was assumed to be 1.3 kg L^{-1}, a standard assumption for the bulk density of surface horizons of mineral soils (Brady, 1984; Hillel, 1982). The 10^9 constant converts the units of mass from kg to µg. For chemicals that have a valid K_{oc}, the K_d can be calculated using a sediment carbon content of 2% (K_{oc}*0.02). An organic carbon content of 2% represents a typical value for a high clay soil that might be used to grow rice in the Mississippi Valley or gulf coast regions but was also used for the listed salmonids in the absence of more region-specific data.

The inputs used for the static water body assessment specific to malathion use on mosquitoes were:

Application rate:	0.5 lbs/acre (consistent with product labels)[1]
Koc:	151 mL/g (consistent with previous assessments[2])
Half life:	3.3 days (consistent with previous assessments[3])

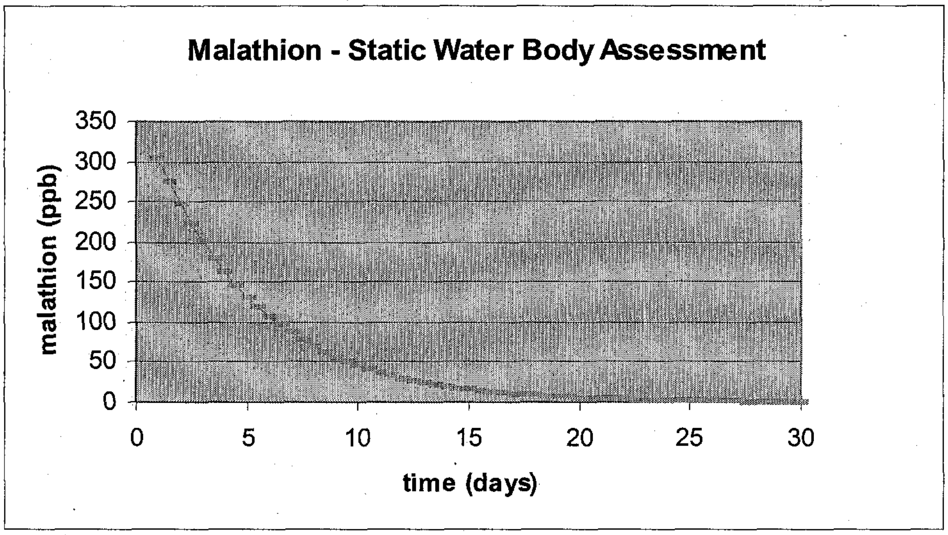
The resulting peak concentration from a single application was 306 ppb. Dividing this concentration by the average 96-hour LC50 for fish (20 ppb) results in a risk quotient of 15.3 which clearly exceeds the acute endangered species LOC of 0.05. Dividing 306 ppb by the LC50 for Isoperla sp., 0.69 ppb, results in a risk quotient of 443 which clearly exceeds the acute LOC for indirect effects of 0.5[3]. The aquatic half life of 3.3 days can be used to estimate the duration that the concentration in the static water body would exceed the LOCs. Assuming first order decay, the LOCs for direct and indirect effects would be exceeded for approximately 13 and 32 days respectively (Figure 1).

[1] E.g. EPA Registration nos. 2935-83, 510-214, and 45385-66. Products with lower maximum use rates and similar directions would result in proportionately lower EECs.

[2] Tier II Aquatic Exposure Assessment for Selected Malathion Agricultural Uses in California, Oregon, and Idaho. October 27, 2004. DP barcode D308617

[3] The LOC for indirect is 0.5 for species without an obligate relationship to another species. Since salmonids are opportunistic feeders they are not considered to have an obligate relationship to any particular prey item.

Figure 1. Malathion concentration in the rice model scenario and decline of residues as a result of aerobic aquatic metabolism.



It is worth emphasizing that the estimated exposure concentration does not represent a concentration that would be expected in common salmonid supporting waters, as it represents a shallow static water body and salmonids are generally found in deeper, flowing water bodies. Rather, it represents an upper bound on the water concentrations, and is therefore suitable for use in screening assessments. The concentrations found in salmonid supporting waters impacted by spraying shallow, nearly-static water bodies would be expected to be less than this value (in some cases much less) due to degradation of the malathion and dilution by untreated water. However, adjusting the dilution factor in the model suggests that in order to reduce exposures below the LOC, the depth of the water body would need to be greater than 33 feet for direct effects and greater than 330 feet for indirect effects.

Flowing Water - AGDISP Stream Assessment

AGDISP version 8.08 is a computer model that can be used to estimate downwind deposition of spray drift from aerial applications. The model contains "Toolbox" screens that can be used to estimate deposition levels in streams and estimate buffer distances required to reduce deposition to acceptable levels. The model was developed by the U.S. Forest Service (Bilanin *et al* 1989). The Spray Drift Task Force field trial data were used to validate the model under agricultural use conditions (Bird *et al* 1996a and 1996b). The model is promising as a tool for estimating resulting concentrations from mosquito control applications as well (Latham 2004).

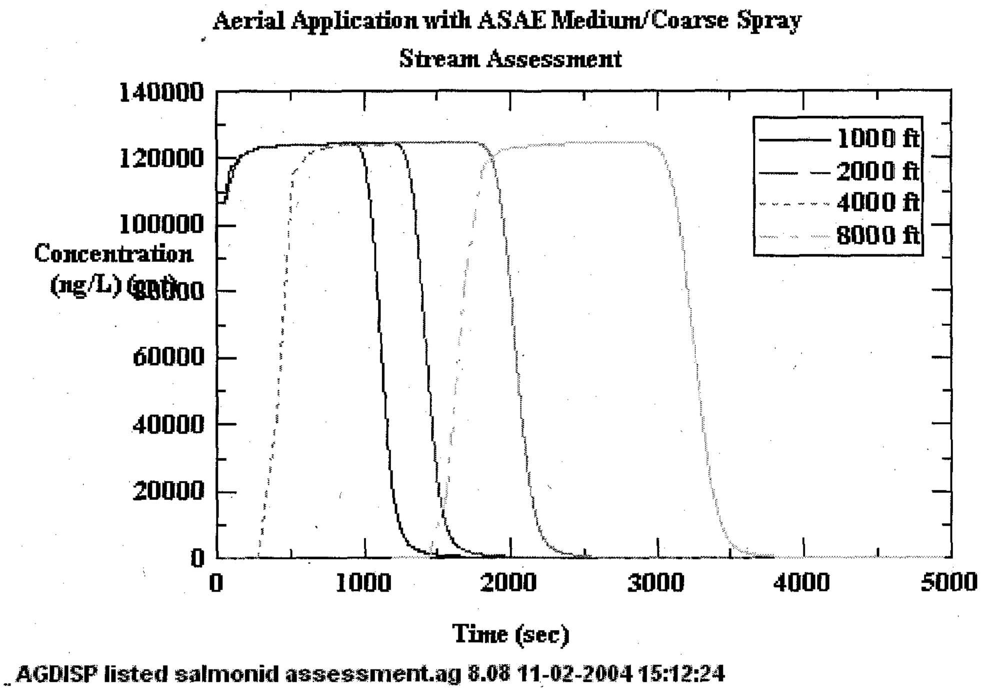
Within the AGDISP model is a "stream assessment" feature for estimating the concentration and duration of concentrations from a pesticide depositing in a flowing water body with variable dimensions and flow. The stream assessment can be used to provide an estimate of malathion concentrations in water bodies more commonly associated with salmonids, and still vulnerable to pesticide contamination. Unlike the interim rice model assessment above, the stream assessment does not take into account partitioning or degradation which would reduce concentrations. Another difference is that only pesticide drift is considered in the stream assessment, direct application to stream which would result in higher concentrations is not considered.

The inputs used for the stream assessment specific to malathion use on mosquitoes were:

Application rate:	0.5 lbs/acre (consistent with product labels)
Release height:	30 ft (conservative estimate based on professional judgement. Consistent application conditions reported by some adulticide applicators)
Distance from the edge of the application area to the center of the stream:	5 ft (conservative assumption consistent with label directions for treating bankside vegetation)
Wind speed:	5 mph (estimate)
Spray line length:	5280 ft (estimate)
Droplet size:	ASAE Medium/Coarse (Consistent with the coarsest spray generally achievable under typical flight speeds of fixed-wing aircraft. Slightly finer sprays would result in higher drift and greater exposures. Much finer sprays, consistent with flying mosquito adulticide applications, would result in less deposition per unit area.)
Stream width:	9.84 ft (Stream assessment default. Considered to be appropriate for a small salmonid bearing stream.)
Stream depth:	1.64 ft (Stream assessment default. Considered to be appropriate for a small salmonid bearing stream.)
Flow rate:	396.3 gal/s (2.24 mph. Stream assessment default. Considered to be appropriate for a small salmonid bearing stream.)
Canopy:	None (conservative assumption)
Other inputs:	AGDISP defaults

The stream assessment outputs the magnitude of concentrations and the duration of exposure in the flowing water body (Figure 2).

Figure 2. Estimated malathion concentrations over time at various distances downstream from the application.



The stream assessment shows that for fish swimming upstream, or other organisms holding their position in a flowing water body, that the duration of exposure is expected to be approximately 30 minutes and the highest concentration expected is approximately 120 ppb (120,000 ng/L). Duration of exposure can affect LC50 values. The data for fish and aquatic invertebrates in Tables 2 and 3 show that 24-hour exposures require higher concentrations to result in LC50 levels compared to 96-hour exposures. Toxicity data is not available for exposure durations on the order of what is predicted in the stream assessment scenario. The using the 24-hour LC50 for fish (90 ppb for bluegill) to estimate risk results in a risk quotient of 1.3 (120 ppb / 90 ppb) which exceeds the LOC 0.05 for direct effects. The using the most sensitive average 24-hour LC50 for aquatic invertebrates (2.7 ppb for Gammarus) to estimate risk results in a risk quotient of 44.4 (120 ppb / 2.7 ppb) which exceeds the LOC 0.5 for indirect effects. By increasing the depth of the stream to 43 or more feet for direct effects or 150 feet or more for indirect effects, the resulting risk quotients are below both LOCs.

Uncertainties

To toxicity of relatively short exposures of malathion, as would be expected in flowing water bodies, is uncertainty in this assessment. The toxicity associated with the shortest available exposure periods (24 hours) was used in this assessment. It is expected that effects to exposed organisms would be lower with shorter exposures but an accurate estimate of toxicity with such short durations of exposure was not available.

The models used to estimate exposure simplify environmental processes and are intended to capture the high-end of potential exposure. The estimated concentrations are 2 orders of magnitude higher than unpublished monitoring data submitted to EFED associated with malathion mosquito adulticide use in the eastern US. The frequency that estimated concentrations occur in the Pacific Northwest, if ever, is unknown.

The label directions for the use of malathion in controlling mosquitoes offer very little mandatory directions or advisory guidance. Other than the application rate, important variables such as release height, wind speed, and droplet size are not specified on the label. Additionally, application intervals are not stated. The assessment conducted is based on a single application and does not account for the possibility of multiple loading events.

It is unknown as to how often malathion applications are made in proximity to salmonid supporting waters. In order for significant exposure to occur, the applications must take place near salmonid habitat.

The exposure values included in this assessment are for direct application to water and spray drift to water and do not include malathion that could result from runoff. Runoff contributions would increase the estimated malathion concentrations.

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