Risk Assessment of Malathion Drift to Home Gardens in the Boll Weevil Eradication Program

Robert Baca, USDA-Animal and Plant Health Inspection Service, Riverdale, MD, USA

Abstract

The Boll Weevil Eradication Program is a cooperative effort between federal agencies, state governments, and cotton growers to systematically eliminate the cotton boll weevil from the United States using integrated pest management techniques including coordinated applications of malathion. USDA Animal and Plant Health Inspection Service monitoring of this program provided field information on malathion application intervals and residues from drift on vegetation near gardens. These data were used to assess the risk to human health from the consumption of contaminated vegetation, which is thought to provide the greatest exposure risk to humans living next to cotton fields in the Program. The estimated dose of malathion ingested from contaminated vegetation was compared to EPA-determined reference doses for malathion. Acute and chronic hazard quotients were calculated using known ranges of the different parameters in order to account for their variability. No acute or chronic risks from program-applied malathion were found, except for when chronic estimations used worst-case scenario parameters in the calculations. These estimations used the highest malathion residues, the highest remaining residues after washing, and the greatest consumption of vegetables. It is unlikely that this estimated chronic risk posed any threat, as it assumed a worst-case daily intake of malathion over a year whereas the chemical was in use by the program for approximately two months. Based on this work, recommendations were made to reduce the worst-case chronic risk scenario.

Introduction

The Boll Weevil Eradication Program is a cooperative effort between federal agencies, state governments, and cotton growers to systematically eliminate the cotton boll weevil (*Anthonomus grandis*) from the United States using integrated pest management techniques including coordinated applications of malathion. Since 1892, when it first entered this country, the boll weevil has plagued U.S. cotton farmers by causing more than $22 billion in losses (Kaplan 2003). Eradication began with a successful program in North Carolina and Virginia in 1978. Since then, the Program expanded to include cotton acreage across the southern tier of the United States and adjacent areas of northern Mexico.

The United States Department of Agriculture's (USDA) Animal and Plant Health Inspection Service (APHIS) employs several monitoring techniques in order to assess the adequacy of Program operations in complying with various laws to protect human health and the environment. This paper involves the human health portion of the monitoring. Monitoring for potential exposure of the public to Program-applied malathion was designed to assess whether Program operations and mitigations were effective in preventing or minimizing drift to sites of human habitation or congregation.

Malathion is used to eradicate the boll weevil and is applied to cotton fields at rates of 87-139 mg/m^2 from aircraft or ground equipment. During the fall of the first year of an eradication program, weekly applications are made to cotton fields until the first killing frost. During subsequent years, applications are triggered by exceeding a trap-count threshold in effect through the first killing frost. The U.S. Environmental Protection Agency (EPA) has approved the use of malathion for the Program and has determined that there is minimal risk to people from Program operations. EPA determined that people are safe from the potential exposure to Program-applied malathion due to dermal exposure to residues, inhalation exposure after aerial application, and incidental ingestion of contaminated turf or soil (EPA 2000). There is at least one other route of potential exposure not considered in the EPA risk assessment that is important in cotton-growing areas: the consumption of contaminated vegetation from home

gardens. It is not uncommon for families to plant vegetable gardens close to cotton fields. The risk associated with consuming home-grown vegetables contaminated with malathion due to incidental drift is evaluated here.

Methods

Data was collected from eradication programs in southeast Missouri and northwest Tennessee from 2001-2003 during the treatment season from June through September. Vegetation samples were collected from areas in or near home gardens that were 4.5-20 m from Program-treated cotton fields shortly after applications of malathion to adjacent cotton fields. Samples were analyzed for malathion using gas chromatography. Using these residue values and parameters detailed below, potential doses of malathion were estimated for people consuming the vegetation from gardens situated very close to cotton fields.

Three potential dose estimates were calculated for adults and children. Central estimates of potential dose were the average of the parameters, and represent the typical dose estimate for the home garden scenario. Upper and lower range estimates of the potential dose were based on the 95% confidence intervals, 5^{th} and 95^{th} percentiles, or actual ranges of the parameters depending on the data available. Potential doses were then compared against acute (0.5 mg/kg/day) and chronic (0.024 mg/kg/day) reference doses for malathion as determined by EPA (2000) in order to calculate a hazard quotient. Hazard quotients <1 indicate no expected risk to human health, while those >1 indicate potential risk to human health. Hazard quotients were calculated as follows:

$$\text{Acute Hazard Quotient} = \text{potential dose} / (\text{acute reference dose})$$
$$\text{Chronic Hazard Quotient} = \text{potential dose} / (\text{chronic reference dose})$$

where potential dose is calculated below and reference doses are taken from the EPA (2000).

$$\text{potential dose} = [\text{malathion on vegetation}] * (\text{intake of homegrown vegetables})$$

where the concentration of malathion on vegetation is calculated below and the intake of homegrown vegetables is taken for adults (20-39 years old) and children (3-5 years old) from EPA (1999).

$$[\text{malathion on vegetation}] = (\text{average daily } [\text{malathion on vegetation}]) * (\%\text{ remaining after washing})$$

where the average daily concentration of malathion on vegetation is calculated below and the percent of malathion remaining after washing is taken from Leyva et al. (1998).

$$(\text{average daily } [\text{malathion on vegetation}]) = (\Sigma\ (\text{initial malathion concentration}/2^{(t/\text{half life of malathion})}) / (\text{interval between applications})$$

where the initial malathion concentration is based on the residues detected on vegetation shortly after application to nearby cotton fields, (t) is a daily time step from day 0 when the application occurs up to the number of days in the interval between applications, the half-life of malathion is from EPA (2000), and the interval between applications is the number of days between applications at the sample sites.

Results and Discussion

The hazard quotients indicated that there was no risk to humans from consuming contaminated home-grown vegetation, except for a chronic risk to children when the high-range parameter estimates were

used (Table 1). Acute hazard quotients were all <1 and would not exceed unity even if a child or adult consumed only unwashed vegetation with the highest malathion residue detected.

Category	Low-range estimate	Central estimate	High-range estimate
Child, acute	<0.001	0.021	0.093
Child, chronic	0.001	0.256	1.259
Adult, acute	<0.001	0.013	0.059
Adult, chronic	0.001	0.153	0.801

Table 1. Results of the hazard quotient calculations. Hazard quotients <1 indicate no risk to human health, >1 indicate a potential risk to human health.

There is a potential risk for long-term human health concerns when conditions over time are conducive to higher malathion residues (i.e. gardens located very close to cotton, winds blowing from the cotton fields towards the gardens), longer half-lives of malathion, poor washing of vegetables, and higher consumption of vegetables; all over the lifetime of the child. Such conditions are not likely to persist for any length of time. Several unlikely events must all happen together over the course of an eradication program for the high-range estimates to be an accurate reflection of risk. It is also important to note that the reference doses are based on a daily intake of a substance over the lifetime of an individual. Potential dose estimates presented here are valid only during the times when malathion is applied to the field, usually no more than a quarter of a year.

This highlights a few difficulties in risk assessment calculations. Chronic reference doses determined by EPA are based on daily exposures over a lifetime, while potential exposure to Program-applied malathion is up to about three months a year at variable application intervals. There is no accurate, accepted method for integrating part-year potential exposures into a whole-year, lifetime, risk estimate. The second difficulty arises when the range of variability in parameters used in the risk assessment is considered. The use of multiple high-range parameter estimates produces an overly conservative estimate of risk, due to the effect of essentially multiplying the low probabilities of each high-range estimate together when calculating the high-range risk estimate. The chances of all of the high-range parameters occurring together for any extended period of time are extremely low.

The first year of the Program tends to have the most aggressive applications of malathion, and therefore the highest potential exposures. After the first year, the interval between applications tends to increase. For example, during the first year of operations in Missouri, the average interval between applications was about 7 days, which increased to 14 days the following year. Recommendations made after 2001 based on monitoring data to change program operations, such as increased buffer zones between cotton fields and gardens, resulted in lower residues detected on vegetation after application. In 2001, the average residue detected on vegetation within 20 m of Program-treated cotton was 15.6 ppm. The average residue detected on similar vegetation was 3.1 and 5.4 ppm in 2002 and 2003, respectively.

References

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