

# Health Consultation

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Public Health Evaluations for Potential Exposures to Fluridone or Endothall Used for Treatment of *Hydrilla verticillata* in the Eno River, Orange and Durham Counties, NC

ENO RIVER HYDRILLA MANAGEMENT PROJECT  
ORANGE AND DURHAM COUNTIES, NC

Prepared by the  
North Carolina Division of Public Health

MARCH 25, 2015

This report was supported by funds from a cooperative agreement with the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services. This document has not been reviewed and cleared by ATSDR.

## **Health Consultation: A Note of Explanation**

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR or ATSDR's Cooperative Agreement Partner which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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## HEALTH CONSULTATION

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March 25, 2015

Mr. Rob Emens  
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Division of Water Resources  
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Mr. Emens,

At the request of the Eno River Hydrilla Management (ERHM) Task Force, the N.C. Division of Public Health (DPH) Health Assessment, Consultation & Education (HACE) Program of the Occupational and Environmental Epidemiology Branch (OEEB) evaluated public health risks associated with use of two proposed herbicides to control *Hydrilla verticillata* in the Eno River. The HACE program evaluated potential exposure to the proposed herbicides in the Environmental Assessment provided by the ERHM Task Force and assessed public health risks associated with exposure to fluridone and endothall.

Attached to this letter you will find the complete evaluation, conclusions, and recommendations. It is the opinion of the OEEB that use of fluridone in the Eno River, even at maximum application rates, is unlikely to result in any adverse public health effects. Use of endothall at maximum application rates carries a small risk of adverse public health effects, especially if drinking water intakes are located downstream of the treatment area. N.C. DPH highly recommends the use of fluridone for hydrilla management over the use of endothall in the Eno River. If the ERHM Task Force chooses to use endothall, it is the recommendation of the N.C. DPH that application rates not exceed 3 mg/L, swimming is restricted during treatment, and downstream drinking water intakes are monitored daily to ensure endothall does not contaminate municipal drinking water.

We will continue to work with the ERHM Task Force to safeguard public health throughout the process of eradicating hydrilla from the Eno River. If you have specific questions about the report, please contact me via email ([beth.dittman@dhhs.nc.gov](mailto:beth.dittman@dhhs.nc.gov)) or by phone (919-707-5906).

Sincerely,

Beth Dittman, M.S.  
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## **Background and Statement of Issues**

The Eno River (Figure 1) is a relatively shallow, swift flowing, Piedmont stream originating in northwest Orange County, North Carolina. From its origin to Falls Lake, the Eno flows through Orange and Durham Counties for approximately 28 miles and encompasses an approximately 150 square mile watershed area. The Eno River includes two drinking water reservoirs upstream of its confluence with the Flat River. The Eno River is regionally and nationally important for its ecological, recreational, and historical resources. Of ecological importance, the Eno provides habitat for sixteen aquatic animal species classified as special status. Additionally, the Eno is known for its biodiversity and good water quality. The Eno River is used extensively for recreational purposes, including an Eno River Festival held every summer. Recreational opportunities such as hiking, camping, paddling, picnicking, fishing, and nature study exist along the Eno River, with many of these opportunities located just outside municipal and developed areas.

The aquatic weed commonly known as hydrilla (*Hydrilla verticillata*) was first detected in the Eno River in 2005 by Eno River State Park staff. Over the next several years, multiple surveys assessed the extent of hydrilla infestation. An intensive survey was organized in the fall of 2013, which determined that roughly 25 miles of the river contained hydrilla with varying densities (ERHM Task Force 2015). Hydrilla is a federally listed and state listed noxious weed. Hydrilla can form extremely dense stands, filling the water column from the bottom to the surface, crowding and outcompeting native vegetation, as well as reducing habitat quantity and quality for native freshwater aquatic animals. The density of hydrilla mats can readily inhibit recreation, especially swimming, boating, and fishing, as well as clog water intakes for municipal and private entities. Additionally, hydrilla provides a habitat for mosquitoes, which can carry and spread human diseases such as West Nile Virus. Hydrilla has also been found to harbor a toxin-producing cyanobacterium associated with Avian Vacuolar Myelinopathy, a lethal disease that can affect plant eating waterfowl.

Control of hydrilla has proven to be difficult due to the fact that the weed has multiple reproductive pathways, including vegetative fragments, tubers, turions, and seeds. Tubers can remain viable in the hydrosol for seven years or longer. These reproductive abilities hinder removal of hydrilla from infested systems. Mechanical controls, such as cutters, cultivators, and dredges often create plant fragments that can spread the infestation, as well as significantly disturb sediments and indiscriminately remove benthic organisms and fish using the plants as habitats. The only proven biological control for hydrilla is the use of triploid grass carp<sup>1</sup>, but these fish eat native submerged plants as well as hydrilla. It is also possible that the grass carp would migrate away from the target areas and significantly impact native aquatic plant populations in other areas of the river system. No physical control measures are feasible for use in the Eno River, largely due to ineffectiveness or negative impacts on native aquatic species.

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<sup>1</sup> Triploid grass carp are genetically modified to prevent reproduction.

The last option for hydrilla management is chemical control through the use of herbicides. Several types of herbicides are approved by the U.S. EPA for the treatment of hydrilla infested waters, and the Eno River Hydrilla Management (ERHM) Task Force has narrowed it down to two possibilities: fluridone (Sonar Genesis<sup>®</sup>), and endothall (Aquathol<sup>®</sup>). These herbicides have been demonstrated to be selective for hydrilla management at low concentrations (ERHM Task Force 2015).

Fluridone (Sonar Genesis<sup>®</sup>) is a systemic herbicide and approved for application concentrations up to 150 µg/L, but hydrilla is sensitive to concentrations as low as 3-5 µg/L. Since fluridone requires sustained contact with the plants, the herbicide is generally applied over a 45-90 day period. Endothall (Aquathol<sup>®</sup>) is a faster-acting contact herbicide, but may still require several weeks for hydrilla knock-down. Endothall is approved for an application concentration up to 5 mg/L, but is often applied at rates of 1-3 mg/L to ensure that the chemical is selective for reduction of hydrilla while minimizing negative effects to other aquatic vegetation. Both herbicides generally leave a viable portion of the lower part of the plant, including tubers and the root crown. For this reason, chemical treatments usually need to be repeated for several years for longer-term control of hydrilla.

The ERHM Task Force has already performed an environmental assessment for the prospective use of these two herbicides in the Eno River. The Health Assessment, Consultation & Education (HACE) Program within the NC Division of Public Health (DPH) undertook an assessment of potential public health effects from the proposed use of two herbicides, fluridone and endothall, in the Eno River. The results of that assessment are presented here.

## **Toxicology Assessment**

### **Fluridone Toxicity**

Fluridone is an herbicide approved by the U.S. EPA for the treatment of aquatic plant pest species, including *Hydrilla verticillata*. It requires prolonged contact time ( $\geq 45$  days) to be effective, resulting in intermediate exposure scenarios, but these applications are usually repeated for several years, resulting in intermittent exposure. The acute toxicity of fluridone is “moderate to low” (EPA 2004). For intermediate length oral exposure studies, liver hypertrophy was seen in mice at the highest tested dose, 200 mg/kg/day, while no adverse health effects were seen in dogs at the same dose. Studies in rats showed maternal and developmental toxicity at 300 and 1000 mg/kg/day, respectively, while similar studies with rabbits indicated both maternal and developmental toxicity at 300 mg/kg/day. Chronic dietary experiments have shown decreased body weights, decreased eosinophil counts, and decreased liver and kidney weights in rats at 81 mg/kg/day. In dogs, chronic exposure resulted in increased liver weights and alkaline phosphatase activity at the highest tested dose, 400 mg/kg/day (Table 6). The U.S. EPA’s chronic reference dose (RfD) for fluridone was developed from a 2-year (chronic) dietary study on mice which showed an increase in alkaline phosphatase activity and hepatocellular hypoplasia

at 50 mg/kg/day. The no observed adverse effect level (NOAEL) for this study is 15 mg/kg/day (Table 6). The U.S. EPA applied a safety factor of 100 for inter- and intra-species variability, resulting in the 0.15 mg/kg/day RfD for chronic oral exposure to fluridone (EPA 2004).

The U.S. EPA Health Effects Division (HED) Cancer Assessment Review Committee evaluated the available data and concluded that the data did not provide evidence for the carcinogenicity of fluridone in either rats or mice.

### **Endothall Toxicity**

Endothall is an herbicide approved by the EPA for the treatment of aquatic weeds, including *Hydrilla verticillata*. The EPA classifies endothall as a dermal irritant and sensitizer, although dermal and ocular effects are generally only observed after exposure to concentrated endothall products. In intermediate oral exposure tests, body weight gain effect NOAELs were determined to be 39 and 11.7 mg/kg/day for rats and dogs, respectively. In developmental toxicity studies in rats, maternal toxicity was not observed at 12.5 mg/kg/day, and no adverse developmental effects were seen at the highest tested dose of 25 mg/kg/day. In rat reproductive studies, proliferative lesions of the gastric epithelium were seen in the parents at 2 mg/kg/day, the lowest dose tested. Reproductive toxicity manifested as decreased pup weights was observed at 60 mg/kg/day, with the NOAEL determined to be 9.4 mg/kg/day. Gastric epithelial hyperplasia was observed in dogs in a chronic toxicity study at 6.5 mg/kg/day, the lowest dose tested. The EPA's chronic reference dose for endothall via ingestion was developed from the 2-generation reproduction toxicity study in rats that showed proliferative lesions of the gastric epithelium at 2 mg/kg/day (Table 9). The U.S. EPA applied a safety factor of 300 for extrapolation from lowest observed adverse effects level (LOAEL) to NOAEL as well as inter- and intra-species variation, resulting in the 0.007 mg/kg/day RfD for chronic exposure to endothall (EPA 2005).

In accordance with the 1999 Draft Guidelines for Cancer Risk Assessments, the Hazard Identification Assessment Review Committee (HIARC) within the EPA classified endothall as “not likely to be carcinogenic to humans” based on the lack of evidence of carcinogenicity in mice or rats.

### **Exposure Assessment for the Eno River**

For all chemicals, exposure routes that were considered are incidental ingestion of river water and dermal contact while swimming, drinking municipal water contaminated with the herbicide, and ingesting fish caught from the treatment area (Table 1). Additionally, the following assumptions were made concerning the potentially exposed populations for all exposure scenarios (see also Table 3):

- Swimming frequency was assumed to be 3 hours per day, two days per week, for the duration of the treatment period (4 months for fluridone and 1.5 months for endothall).

- For incidental ingestion of water while swimming, the 95<sup>th</sup> percentile ingestion rate was used for each age group.
- For dermal exposure while swimming, the 95<sup>th</sup> percentile for skin surface area was used for each age group.
- For ingestion of tap water, the 95<sup>th</sup> percentile ingestion rate was used for each age group.
- For fish ingestion by adult consumers, an intake rate of 170 g/day was used, which is consistent with subsistence populations, not general anglers. This ingestion rate is consistent with the current N.C. DPH exposure parameters for health risk associated with fish ingestion.
- For fish ingestion by children, an intake rate of 16.5 g/day was used, which is consistent with the EPA's Exposure Factor Handbook (2011) 95<sup>th</sup> percentile intake rate for children aged 0-9 years.
- For all adult dose calculations, a body weight of 70 kg was used.
- Sensitive populations considered were pregnant females, bottle-fed infants from birth to <1 year old, and children aged 2 to <6 years old. Infants exposed via contaminated drinking water receive the maximum estimated dose of any age group due to their high ingestion rate relative to their small body size. The 2 to <6 year age range was chosen due to their smaller size and behavioral differences (i.e. higher incidental ingestion rates), which results in exposure dose estimates that are likely higher than those received by older children.
- Infants less than a year old were assumed to be exposed via the drinking water pathway only. Infants less than a year are unlikely to go swimming in a river system, and are unlikely to consume fish.

Note that these assumptions are health-protective in that they will likely result in an overestimate of dose received by the exposed populations. Equations used to calculate estimated doses can be found in Appendix A. Estimated doses were compared to the relevant EPA chronic reference dose (RfD) for each compound. The RfD is an estimate of daily exposures to a substance that is likely to be without a discernable risk of non-cancer adverse effects to the general human population, including sensitive subgroups, during a lifetime of exposure.

### **Fluridone exposure assessment**

For fluridone dose calculations, the following chemical specific exposure scenario assumptions were made (see also Table 2):

- Concentration of fluridone in the water (both swimming and drinking) was assumed to be 150 µg/L, which is the maximum application rate. In reality, the target application rate is 30 times lower at 5 µg/L.
- For ingestion of tap water, fluridone concentration was assumed to be 150 µg/L. In reality, the maximum allowed application rate within 0.25 miles of a potable water intake is 20 µg/L, and the target application rate is 5 µg/L.



- For fish ingestion, the concentration in fish tissue was assumed to be 0.5 mg/kg, which is the residue tolerance level.

Assuming the highest application rate of the herbicide, in addition to assuming high ingestion rates of water and fish, result in what is likely to be a high overestimation of the dose of fluridone that the exposed populations receive. These assumptions were made in order to safeguard public health.

#### *Recreational User Fluridone Exposure*

For recreational users of the Eno River, the likely exposure routes would be incidental ingestion and dermal contact with the water while swimming and ingestion of fish caught in the Eno. Estimated exposure doses received via incidental ingestion while swimming in treated water range from 0.00004 to 0.0003 mg/kg/day. Estimated exposure doses via dermal contact while swimming range from 0.00002 to 0.00003 mg/kg/day. Consumption of fish caught in treated waters yields an estimated fluridone exposure dose of 0.0005 to 0.0012 mg/kg/day.

Cumulatively, the maximum estimated fluridone dose received by recreational users range from 0.0008 – 0.0013 mg/kg/day, which is 117-188 times lower than the EPA's chronic reference dose (RfD) of 0.15 mg/kg/day. It is important to note that the RfD is developed to consider daily doses over a lifetime of exposure that are anticipated to result in no adverse health effects.

Estimated exposure doses for recreational users exposed to the Eno River treated at the target fluridone application rate range from 0.0005 to 0.0012 mg/kg/day, 123-300 times lower than the RfD. We conclude that exposure to fluridone in the Eno River by recreational users is unlikely to result in adverse health effects.

#### *Municipal Water User Fluridone Exposure*

Municipal water users include people exposed via ingestion of tap water at their homes or businesses. The maximum estimated fluridone dose received by municipal water users range from 0.005-0.022 mg/kg/day, which is 7-28 times lower than the EPA's chronic RfD of 0.15 mg/kg/day. It is important to note that in order to remain health-protective in our assessment, these dose estimates were calculated assuming a fluridone concentration of 150 µg/L, which is much higher than both the allowable application rate near potable water intakes (20 µg/L) and the target application rate (5 µg/L). Estimated exposure doses at the target application rate range from 0.0002 to 0.0007 mg/kg/day, 210-845 times lower than the RfD, and the RfD is protective of daily lifetime exposure. We conclude that exposure to fluridone via municipal water drawn from the Eno River during treatment is unlikely to result in adverse health effects.

#### *Aggregate Fluridone Exposure*

In the unlikely scenario that a person is exposed to the maximum levels of fluridone through recreational activities as well as municipal water supplies, the total estimated dose received via all four pathways remains more than an order of magnitude lower than the EPA's chronic

reference dose (RfD) for daily lifetime exposure of 0.15 mg/kg/day (Table 4), with the exception of bottle-fed infants less than a year old. The estimated exposure dose for infants exposed to fluridone in drinking water at the maximum application rate remains below the RfD. Using the anticipated fluridone application rate of 5 µg/L, the total estimated dose received is 105-210 times lower than the RfD (Table 5). Removing exposure via fish ingestion, the estimated dose is 210-840 times lower than the RfD. We conclude that the use of fluridone in the Eno River at the recommended application concentration for the control of *Hydrilla verticillata* is unlikely to cause any negative health effects and thus does not pose a public health hazard.

#### *Fluridone-related Chemical Exposure*

Consideration was given to two other compounds associated with fluridone use: propylene glycol and N-methyl formamide (NMF). Propylene glycol is listed as an inert ingredient on the Sonar Genesis® label, and NMF is the primary degradation product of fluridone. Except for chemical specific parameters (Table 2), all other exposure parameters used for propylene glycol and NMF dose calculations were the same values used for fluridone dose estimates (Table 3), again resulting in a likely overestimation of exposure dose.

For propylene glycol, it was assumed that the product applied was 60% propylene glycol and 5% active ingredient, which yields a maximum application concentration of 1.8 mg propylene glycol/L. The maximum estimated aggregate doses of propylene glycol are 78-300 times lower than the RfD of 20 mg/kg/day. Using the anticipated application rate of the product (0.005 mg/L of active ingredient, yielding a propylene glycol concentration of 0.06 mg/L), total estimated doses are 2300-6000 times lower than the RfD.

For NMF analysis, the maximum daily fluridone to NMF conversion rate of 74% was assumed, resulting in a maximum NMF concentration of 19.91 µg/L after correcting for molecular weight. Using this concentration, calculated maximum estimated cumulative doses of NMF are 35-60 times lower than the RfD of 0.10 mg/kg/day. The anticipated application rate of the product (5 µg/L) yields a NMF concentration of 0.664 µg/L. With this more realistic concentration, total estimated doses of NMF received by populations exposed to treated water are 80-1000 times lower than the RfD.

We conclude that the use of fluridone in the Eno River at the recommended application concentration for the control of *Hydrilla verticillata* is unlikely to result in chemical exposures that have adverse public health consequences.

#### **Endothall exposure assessment**

For endothall dose calculations, the following chemical specific exposure scenario assumptions were made (see also Table 2):

- Concentration of endothall in the water (both swimming and drinking) was assumed to be 5 mg/L, which is the maximum application rate.
- For ingestion of tap water, endothall concentration was assumed to be 5 mg/L. In reality, the maximum contaminant level (MCL) is 0.1 mg/L.
- For fish ingestion, the concentration in fish tissue was assumed to be 0.1 mg/kg, which is the residue tolerance level.

Assuming the highest application rate of the herbicide, in addition to assuming high ingestion rates of water and fish, result in what is likely to be an overestimation of the dose of endothall that the exposed populations receive. These assumptions were made in order to safeguard public health.

#### *Recreational User Endothall Exposure*

For recreational users of the Eno River, the likely exposure routes would be incidental ingestion and dermal contact with the water while swimming and ingestion of fish caught in the Eno. Estimated exposure doses received via incidental ingestion while swimming in treated water range from 0.0005 to 0.003 mg/kg/day. Estimated exposure doses via dermal contact while swimming range from 0.000001 to 0.000002 mg/kg/day. Consumption of fish caught in treated waters yields an estimated fluridone exposure dose of 0.00009 to 0.0002 mg/kg/day. Cumulatively, the maximum estimated endothall dose received by recreational users of the Eno ranged from 0.0008-0.0038 mg/kg/day, which is 1.8-9 times lower than the EPA's chronic reference dose of 0.007 mg/kg/day. It is important to note that the RfD is developed to compare daily lifetime exposures to a chemical, whereas exposure to endothall in the Eno River is likely to occur only intermittently. We conclude that recreational users of the Eno River who do not drink municipal water drawn from the treatment area are unlikely to be at risk of adverse health effects from endothall exposure.

#### *Municipal Water User Endothall Exposure*

Municipal water users include people exposed via ingestion of tap water at their homes or businesses. The maximum estimated endothall dose calculated for municipal water users range from 0.177-0.713 mg/kg/day, which is 25-102 times higher than the chronic RfD. However, these doses were calculated using a water concentration of 5 mg/L, the maximum allowed application rate. The maximum contaminant level (MCL) for endothall is 0.1 mg/L, set by the EPA as an enforceable public drinking water regulation that is protective of public health while considering economic and technological constraints. Using a drinking water concentration of 0.1 mg/L, estimated endothall doses range from 0.0035-0.014 mg/kg/day. The estimated exposure dose for bottle-fed infants under the age of one is two times the RfD, indicating the possibility for adverse health effects for this population. We recommend that if endothall is used in the Eno River, downstream drinking water intakes should be frequently monitored (i.e. daily during treatment and 15 days post-treatment) to ensure that endothall is not present.

### *Aggregate Endothall Exposure*

In the unlikely scenario that a person is exposed to the maximum levels of endothall through recreational activities as well as municipal water supplies, the total estimated dose received through all four pathways ranged from 0.18-0.71 mg/kg/day, which is 25-102 times higher than the EPA chronic RfD of 0.007 mg/kg/day (Table 7). It is important to note that the RfD is developed to compare daily lifetime exposures to a chemical, whereas exposure to endothall in the Eno River is likely to occur only intermittently.

A second endothall exposure scenario was considered to more accurately reflect the expected exposure conditions that will be experienced at the Eno River. In this scenario more realistic exposure concentrations of 3 mg/L in swimming water and 0.1 mg/L in drinking water were used. 3 mg/L is the application rate used by other entities for hydrilla management, and 0.1 mg/L is the MCL set by the EPA for endothall residues in drinking water. To remain health-protective, all other assumptions listed above were still used, including 95<sup>th</sup> percentile skin surface areas, 95<sup>th</sup> percentile water intake rates, fish ingestion rates by adults of 170 g/day, as well as a body weight of 70kg for adults. Using this more realistic, but still health protective, approach, the doses of endothall exposed populations are expected to receive range from 0.6-2 times the RfD of 0.007 mg/kg/day (Table 8). The highest estimated dose is 0.014 mg/kg/day, which is still likely to be an overestimate of the dose received by exposed populations due the conservative assumptions made regarding water ingestion rates. The RfD was developed considering a daily exposure to endothall over a lifetime, but the health effects seen in toxicity studies with rats occurred after an intermediate exposure period of 13 weeks. The estimated dose received by bottle-fed infants using municipal water from a source downstream of treatment represents a possible health risk.

We conclude that use of endothall in the Eno River for management of *Hydrilla verticillata* may have a small risk of resulting in negative public health effects, particularly for small children who may receive the highest dose, or for other subpopulations with particular susceptibilities such as pre-existing skin conditions or gastrointestinal issues. In addition, dogs show particular sensitivity to the adverse effect of endothall ingestion and their exposure may be a concern during the Eno River Festival or associated with nearby recreational areas. In order to consider a more accurate exposure scenario, we are requesting more information from the task force regarding the target application concentration, as well as application duration and frequency. We also request information regarding the river flow rate to determine the amount of time it will take endothall-treated water to flow from the application site to the nearest downstream drinking water intake in order to better estimate the drinking water concentration.

### **Child Health Considerations**

The N.C. DPH recognizes there are unique exposure risks concerning children that do not apply to adults. Children are at a greater risk than are adults to certain kinds of exposures to hazardous

substances. Because they play outdoors and because they often carry food into contaminated areas, children are more likely to be exposed to contaminants in the environment. They are also smaller, resulting in higher doses of chemical exposure per body weight compared to adults. If toxic exposures occur during critical growth stages, the developing body systems of children can sustain permanent damage. Probably most important, however, is that children depend on adults for risk identification and risk management, housing, and access to medical care. Thus, adults should be aware of public health risks in their community, so they can guide their children accordingly. Child-specific exposure situations and health effects are taken into account in N.C. DPH health effect evaluations.

In this assessment, exposure dose estimates were calculated for infants and small children at an age range anticipated to experience the highest doses and to ensure that this population was not at an unacceptable risk level for exposure to the proposed herbicides. To remain health-protective of this population, 95<sup>th</sup> percentile or reasonable maximum exposure factors were used when estimating exposure doses to all chemicals (Table 3) (ATSDR 2014a; ATSDR 2014b; EPA 2011).

## **Conclusions**

**Conclusion 1: The use of fluridone in the Eno River, even at the maximum application rate, is unlikely to pose a risk to public health.**

Basis for conclusion 1: Using an exposure scenario which likely overestimates the potential dose of fluridone received by exposed populations, including sensitive subpopulations, maximum exposure doses are nearly an order of magnitude lower than the RfD of 0.15 mg/kg/day (Table 4). Additionally, using the same health-protective exposure scenario, estimated doses of fluridone related chemicals (propylene glycol and N-methyl formamide) were 35-300 times lower than their respective RfD values.

Recommendation 1a: Drinking water intakes downstream from fluridone treatment should be frequently monitored to ensure that fluridone concentrations do not surpass label permitted application rates of 20 µg/L at potable water intakes, as drinking water accounted for the largest dose under most exposure scenarios considered. The ERHM Task Force has already stated a plan to sample near the start, middle, and end of the treatment zone every 1 to 2 weeks following more frequent testing during the first week of the treatment process.

Recommendation 1b: The ERHM Task Force should ensure that access is restricted to the herbicide drip infusion system. Restricting access will ensure that the general population is not exposed to the likely higher concentrations of herbicide located directly at the application point. Additionally, controlling access will prevent tampering with the drip infusion system. Any unauthorized tampering may result in unpredictable fluridone concentrations within the water body.

Recommendation 1c: The ERHM Task force should ensure that residents in homes near the drip infusion system are informed about the project, any potential risks, and how to reduce their exposure to the treated water. This includes advice to limit swimming and fishing immediately downstream from the system, not using treated water to irrigate home gardens, and using municipal water supplies for drinking, bathing, and cooking.

**Conclusion 2: The use of endothall may pose a public health risk, especially for small children. Every effort should be made to ensure that drinking water sources are not contaminated with endothall. More information is needed from the task force on target concentrations and application duration and frequency.**

Basis for conclusion 2: Using a conservative endothall exposure scenario and the maximum application rate, calculated exposure doses exceeded the RfD of 0.007 mg/kg/day, with the highest doses calculated for infants aged birth to <1 year old (Table 7). A more realistic scenario resulted in a maximum estimated dose two times higher than the RfD (Table 8), but assumptions were made regarding the application concentration and duration for this scenario. To ensure this scenario is realistic, confirmation of application rates is needed from the task force.

Recommendation 2a: Drinking water intakes downstream from endothall treatment should be frequently monitored to ensure that endothall is not in the municipal water, as this exposure route accounted for the largest dose under every exposure scenario considered. The ERHM Task Force has already stated a plan to sample near the start, middle, and end of the treatment zone every 1 to 2 weeks following more frequent testing during the first week of the treatment process. We recommend that the ERHM Task Force also coordinate with local water treatment plants to ensure proper monitoring and treatment plans are in place.

Recommendation 2b: Signs should be posted at popular recreational areas along the treated areas of the Eno River, warning of potential adverse health effects associated with endothall exposure. These signs may also include a warning for dog owners that dogs may be more sensitive to the effects of endothall ingestion. Other means to ensure that recreational users and subsistence fisher users of the Eno River are aware of the pesticide treatments should be made.

Recommendation 2c: Swimming should be restricted in the treatment areas for at least 24-hours after endothall application. The EPA identifies risk estimates on the day of application to be the key concern for recreational endothall exposure (EPA 2005). Additionally, a 24-hour swimming restriction is consistent with Special Local Need (SLN) labels for endothall use imposed by other states and will protect the public from exposures to the highest levels of the herbicide (NY 2008; Tomkins Co. 2013).

Recommendation 2d: The ERHM Task Force should ensure that access is restricted to the herbicide drip infusion system. Restricting access will ensure that the general population is not exposed to the likely higher concentrations of herbicide located directly at the application point. Additionally, controlling access will prevent tampering with the drip infusion system. Any

unauthorized tampering may result in unpredictable endotoxin concentrations within the water body.

Recommendation 2e: The ERHM Task force should ensure that residents in homes near the drip infusion system are informed about the project, any potential risks, and how to reduce their exposure to the treated water. This includes advice to avoid swimming and fishing immediately downstream from the system, not using treated water to irrigate home gardens, and using municipal water supplies for drinking, bathing, and cooking.

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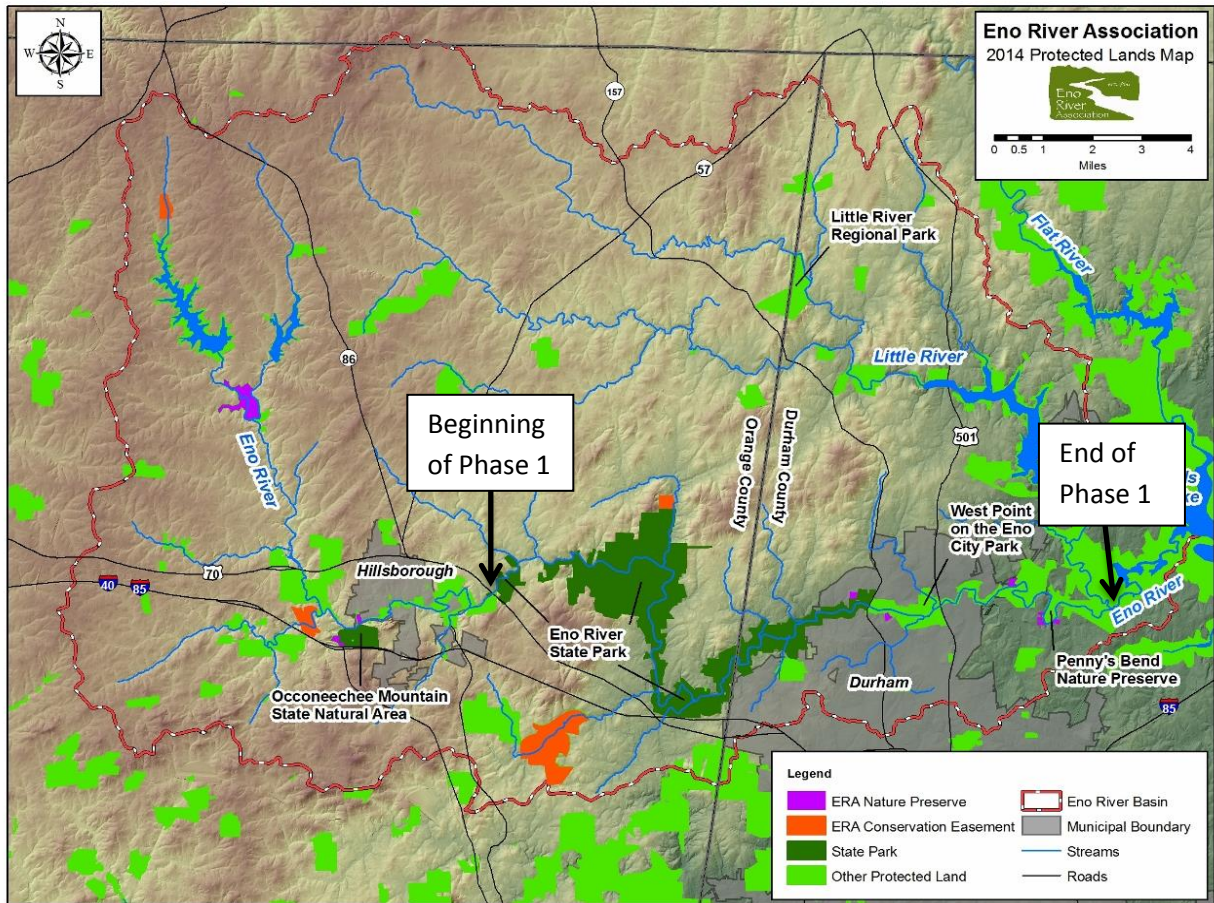
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**Figure 1.** Map of the Eno River and the proposed treatment area (Hydrilla Task Force 2015).

**Table 1.** Conceptual site model for Eno River hydrilla management exposure pathways.

Source	Environmental medium and transport	Exposure point	Exposure route	Potentially exposed populations
Herbicide applied for hydrilla management	Water	Eno river water	Incidental ingestion	Swimmers – adult and child
			Dermal contact	
	Public water supply	Ingestion	Municipal residents	
	Biota	Fish caught in river	Ingestion	Recreational and subsistence fishermen and their families

**Table 2.** Chemical specific exposure parameters used to calculate estimated exposure doses for Eno River Hydrilla management herbicides.

Chemical	Maximum application rate (mg/L) <sup>a</sup>	Anticipated application rate (mg/L) <sup>a</sup>	EPA maximum contaminant level (mg/L)	Application duration (months)	Fish residue tolerance level (mg/kg)	Permeability coefficient (K <sub>p</sub> ) (cm/hr)
Fluridone	0.15	0.005	NA <sup>b</sup>	4	0.5	0.0004
Endothall	5	3	0.1	1.5	0.1	0.00000882
N-methyl formamide <sup>c</sup>	0.0199	0.00066	NA	4	NA	0.00017
Propylene glycol <sup>d</sup>	1.8	0.06	NA	4	NA	0.0000948

Note: mg/L = milligram of compound per liter of water; mg/kg = milligram of compound per kilogram of fish tissue; K<sub>p</sub> = partition coefficient for dermal exposure; cm/hr = centimeter per hour

- In text, fluridone application rates are given in µg/L. The conversion factor is 1000 µg/L = 1 mg/L.
- NA = Not applicable. MCL for that compound has not been set by the EPA
- NMF is the primary degradation product of fluridone. Application rates were calculated based on a maximum daily conversion rate of 74% and corrected for molecular weight.
- Propylene glycol is listed as an inert ingredient on the Sonar Genesis® label (fluridone). Application rates were calculated assuming the product was 5% active ingredient (minimum listed on label) and 60% propylene glycol (maximum listed on label).

**Table 3.** Population specific exposure parameters used to calculate estimated exposure doses of herbicides proposed for Eno River hydrilla management.

Population	Body weight (kg)	Drinking water ingestion rate (L/day) <sup>a</sup>	Swimming water ingestion rate (L/hr) <sup>a</sup>	Skin surface area (cm <sup>2</sup> ) <sup>b</sup>	Fish intake rate (g/day) <sup>c</sup>
Infants Birth to <1 year <sup>d</sup>	7.8	1.113	NA <sup>e</sup>	NA <sup>e</sup>	NA <sup>e</sup>
Children 2 to <6 years	17.4	0.977	0.12	9500	16.5
Adults	70	3.092	0.071	24300	170
Pregnant women	73	2.589	0.071	24300	170

Note: kg = kilogram; L/day = liters of water consumed per day; L/hr = liters of water ingested per hour of swimming; cm<sup>2</sup> = square centimeters of skin exposed during swimming; g/day = grams of fish consumed per day

- Reasonable maximum exposure value for age group (ATSDR 2014a).
- EPA Exposure Factors Handbook Table 7-9: 95<sup>th</sup> percentile value for age group (EPA 2011).
- EPA Exposure Factors Handbook Table 10-13: 95<sup>th</sup> percentile value for children aged 0 to <9 years old (EPA 2011).
- This age range represents the maximum dose levels for health risk assessment. Refers to bottle-fed infants only.
- Infant exposure was assumed to occur only through the drinking water pathway.

**Table 4.** Aggregate estimated fluridone dose for populations potentially exposed to the Eno River during treatment, assuming fluridone is present in water at the maximum application concentration of 0.15 mg/L. Values in bold represent the exposure pathway with the highest estimated dose for each age group.

Exposed Person	Incidental water ingestion dose (mg/kg/day)	Dermal exposure dose (mg/kg/day)	Drinking water ingestion dose (mg/kg/day)	Fish ingestion dose (mg/kg/day)	Total Estimated Dose (mg/kg/day)	RfD (mg/kg/day)	Hazard Quotient (HQ) (total dose/RfD)
Infants Birth to <1 year	NA <sup>a</sup>	NA <sup>a</sup>	<b>2.14E-02</b>	NA <sup>a</sup>	0.0214	0.15	0.1427
Child 2 to <6 years	2.95E-04	2.84E-05	<b>8.42E-03</b>	4.74E-04	0.0092	0.15	0.0632
Adult	4.33E-05	1.80E-05	<b>6.63E-03</b>	1.21E-03	0.0079	0.15	0.0527
Pregnant female	4.15E-05	1.66E-05	<b>5.32E-03</b>	1.16E-03	0.0065	0.15	0.0436

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

- Infant exposure was assumed to occur only through the drinking water pathway.

**Table 5.** Aggregate estimated fluridone dose for populations potentially exposed to the Eno River during treatment, assuming fluridone is present in water at the target application concentration of 0.005 mg/L. Values in bold represent the exposure pathway with the highest estimated dose for each age group.

Exposed Person	Incidental water ingestion dose (mg/kg/day)	Dermal exposure dose (mg/kg/day)	Drinking water ingestion dose (mg/kg/day)	Fish ingestion dose (mg/kg/day)	Total Estimated Dose (mg/kg/day)	RfD (mg/kg/day)	Hazard Quotient (HQ) (total dose/RfD)
Infants Birth to <1 year	NA <sup>a</sup>	NA <sup>a</sup>	<b>7.13E-04</b>	NA <sup>a</sup>	0.0007	0.15	0.0048
Child 2 to <6 years	9.82E-06	9.46E-07	2.81E-04	<b>4.74E-04</b>	0.0008	0.15	0.0052
Adult	1.44E-06	6.01E-07	2.21E-04	<b>1.21E-03</b>	0.0014	0.15	0.0096
Pregnant female	1.38E-06	5.53E-07	1.77E-04	<b>1.16E-03</b>	0.0013	0.15	0.0090

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

a. Infant exposure was assumed to occur only through the drinking water pathway.

**Table 6.** Summary of toxicity tests used by the EPA for the human health risk assessment portion of the pesticide reregistration process for fluridone and used for development of reference dose (EPA 2005). The EPA RfD for fluridone is 0.15 mg/kg/day.

Exposure route	Time course	Species	Endpoint	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	Study Year
Dermal	Intermediate (3-weeks)	Rabbit	Decreased kidney weights	384	768	1981
Oral	Intermediate (90-day)	Mice	Increased centrilobular hypertrophy of the liver	15	25	1978
		Rat	Increased liver and kidney weights	25	44	1978
		Dog	No effects observed	>250	ND <sup>a</sup>	1978
	Chronic (2 - year)	Rat	Decreased body weights; increased liver and kidney weights	7.65	25.15	1980
		Mouse	Increase alkaline phosphatase activity; increased incidence of hepatocellular hyperplasia	15 <sup>b</sup>	50	1981-1982
	Chronic (1-year)	Dog	Increased liver weights; increased alkaline phosphatase activity	150	400	1981
	Chronic (3-generation)	Rat	Decreased pup weight	36	112	1980
			No parental, reproductive, or developmental effects observed	112	ND	

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

a. ND = Not determined. The highest dose tested resulted in no observed effects.

b. Value for the most sensitive endpoint from studies and endpoint used to develop chronic reference dose (RfD).

**Table 7.** Aggregate estimated endothall dose for populations potentially exposed to the Eno River during treatment, assuming endothall is present in water at the maximum application concentration of 5 mg/L. Values in bold represent the exposure pathway with the highest estimated dose for each age group.

Exposed Person	Incidental water ingestion dose (mg/kg/day)	Dermal exposure dose (mg/kg/day)	Drinking water ingestion dose (mg/kg/day)	Fish ingestion dose (mg/kg/day)	Total Estimated Dose (mg/kg/day)	RfD (mg/kg/day)	Hazard Quotient (HQ) (total dose/RfD)
Infants Birth to <1 year	NA <sup>a</sup>	NA <sup>a</sup>	<b>7.13E-01</b>	NA <sup>a</sup>	7.13E-01	0.007	101.9
Child 2 to <6 years	3.68E-03	2.09E-06	<b>2.81E-01</b>	9.48E-05	0.285	0.007	40.65
Adult	5.42E-04	1.33E-06	<b>2.21E-01</b>	2.43E-04	0.222	0.007	31.66
Pregnant female	5.19E-04	1.22E-06	<b>1.77E-01</b>	2.33E-04	0.178	0.007	25.44

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

a. Infant exposure was assumed to occur only through the drinking water pathway.

**Table 8.** Aggregate estimated endothall dose for populations potentially exposed to the Eno River during treatment, assuming endothall is present in swimming water at the anticipated application concentration of 3 mg/L and in drinking water at the MCL of 0.1 mg/L. Values in bold represent the exposure pathway with the highest estimated dose for each age group.

Exposed Person	Incidental water ingestion dose (mg/kg/day)	Dermal exposure dose (mg/kg/day)	Drinking water ingestion dose (mg/kg/day)	Fish ingestion dose (mg/kg/day)	Total Estimated Dose (mg/kg/day)	RfD (mg/kg/day)	Hazard Quotient (HQ) (total dose/RfD)
Infants Birth to <1 year	NA <sup>a</sup>	NA <sup>a</sup>	<b>1.42E-02</b>	NA <sup>a</sup>	1.42E-02	0.007	2.04
Child 2 to <6 years	2.21E-03	1.25E-06	<b>5.61E-03</b>	9.48E-05	7.92E-03	0.007	1.13
Adult	3.25E-04	7.95E-07	<b>4.42E-03</b>	2.43E-04	4.99E-03	0.007	0.71
Pregnant female	3.12E-04	7.31E-07	<b>3.55E-03</b>	2.33E-04	4.09E-03	0.007	0.58

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

a. Infant exposure was assumed to occur only through the drinking water pathway.

**Table 9.** Summary of toxicity tests used by the EPA for the human health risk assessment portion of the pesticide reregistration process for endothall and used for development of reference dose (EPA 2005). The EPA RfD for endothall is 0.007 mg/kg/day.

Exposure route	Time course	Species	Endpoint	NOAEL (mg/kg/day)	LOAEL (mg/kg/day)	Study Year
Dermal	Intermediate - 3 weeks	Rat	Decreased weight gain	ND <sup>a</sup>	30	1994
Oral	Intermediate – 90 days	Rat	Body weight deficits	39	118	1994
	Intermediate – 13 weeks	Dog	Decreased weight gain	11.7	27.5	1994
	Chronic (>1 year)	Rat	Maternal - Decreased weight gain	12.5	25	1993
			Developmental - no effects observed	25	ND	
			Parental - lesions of gastric epithelium	ND	2 <sup>b</sup>	1993 and 1995
			Reproductive - decreased pup weights	9.4	60	
Dog	Gastric epithelial hyperplasia	ND	6.5	1987		

Note: mg/kg/day = milligram of compound per kilogram of body weight per day

- a. ND = Not determined. Either the highest dose tested resulted in no observed effects, or the lowest dose tested caused adverse effects.
- b. Value for the most sensitive endpoint from studies and endpoint used to develop chronic reference dose (RfD).



## **Appendix A: Exposure Dose Equations**

All equations used to estimate exposure dose for exposure to fluridone or endothall are shown below, and can also be found in the ATSDR Public Health Assessment Guidance Manual (ATSDR 2005). Chemical-specific values for use in these equations can be found in Table 2. Population-specific values for use in these equations can be found in Table 3 and are consistent with ATSDR guidance (ATSDR 2014a, ATSDR 2014b) and the EPA Exposure Factors Handbook (EPA 2011).

### **Ingestion of contaminants present in drinking water**

Exposure doses for ingestion of contaminants present in drinking water are calculated using the maximum and anticipated concentrations of contaminants in milligrams per liter (mg/L). The following equation is used to estimate the exposure doses resulting from ingestion of contaminated drinking water:

$$ED_w = \frac{C \times IR \times EF}{BW}$$

Where:

- ED<sub>w</sub> = exposure dose water (mg/kg/day)
- C = contaminant concentration (mg/L)
- IR = intake rate of contaminated medium (liters/day)
- EF = exposure factor (unitless) = 1 for drinking water
- BW = body weight (kilograms)

### **Incidental ingestion of contaminants present in swimming water**

Exposure doses for incidental ingestion of contaminants present in swimming water are calculated using the maximum and anticipated concentrations of contaminants in milligrams per liter (mg/L). The following equation is used to estimate the exposure doses resulting from incidental ingestion of contaminated water while swimming:

$$ED = \frac{C \times IR \times ET \times EF}{BW}$$

Where:

- ED = exposure dose water (mg/kg/day)
- C = contaminant concentration (mg/L)
- IR = intake rate of contaminated medium (liters/hr)
- ET = Event time (hours/day)
- EF = exposure factor (unitless)
- BW = body weight (kilograms)

Note:

$$EF = \frac{F \times ED}{AT}$$

Where:

- F = Frequency of exposure (days/year)
- ED = Exposure duration (years)
- AT = Averaging time (ED x 365 days/year)

Note: In our fluridone exposure scenario, F = 34.64 days/year and ED = 7 years. For our endothall exposure scenario, F = 12.99 days/year and ED = 7 years.

### **Dermal contact with contaminants present in swimming water**

Exposure doses for dermal contact with contaminants present in swimming water are calculated using the maximum and anticipated concentrations of contaminants in milligrams per liter (mg/L). The following equation is used to estimate the exposure doses resulting from dermal contact while swimming:

$$ED = \frac{C \times K_p \times SA \times ET \times CF}{BW}$$

Where:

- ED = exposure dose (mg/kg/day)
- C = contaminant concentration (mg/L)
- K<sub>p</sub> = dermal permeability coefficient (cm/hr)
- SA = exposed body surface area (cm<sup>2</sup>)
- ET = exposure time (hours/day)
- CF = conversion factor (1 L/1000 cm<sup>3</sup>)
- BW = body weight (kg)

Note: ET = 0.866 hours/day for the purposes of this assessment.

### **Ingestion of contaminants present in biota (fish)**

Exposure doses for ingestion of contaminants present in biota (specifically fish) are calculated using the tolerance residue level for fish tissue set by the U.S. EPA in units of milligram per kilogram (mg/kg). The following equation is used to estimate the exposure doses resulting from consumption of contaminated fish:

$$ED = \frac{C \times IR \times AF \times EF \times CF}{BW}$$

Where:

- ED = exposure dose (mg/kg/day)
- C = contaminant concentration (mg/kg)
- IR = intake rate of contaminated media (mg/day)
- AF = bioavailability factor (unitless)
- EF = exposure factor (unitless) = 1 for daily fish consumption
- CF = conversion factor (10<sup>-6</sup> kg/mg)
- BW = body weight (kg)

Note: AF is assumed to equal 1 for the purposes of this assessment.

## **Appendix B: Glossary of Terms and Abbreviations**

### **Absorption**

The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

### **Acute**

Occurring over a short time [compare with chronic].

### **Acute exposure**

Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

### **Adverse health effect**

A change in body function or cell structure that might lead to disease or health problems

### **Carcinogen**

A substance that causes cancer.

### **Chronic**

Occurring over a long time [compare with acute].

### **Chronic exposure**

Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

### **cm/hr**

Centimeter per hour. Unit used to express permeability coefficient ( $K_p$ )

### **Concentration**

The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

### **Contaminant**

A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

### **Dermal**

Referring to the skin. For example, dermal absorption means passing through the skin.

### **Dermal contact**

Contact with (touching) the skin [see route of exposure].

**Dose**

The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

**Environmental media**

Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

**Environmental media and transport mechanism**

Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

**EPA**

United States Environmental Protection Agency.

**Exposure**

Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

**Exposure assessment**

The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

**Exposure pathway**

The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

**g/day**

Grams per day. Unit used to express fish intake rate.

**Hazard Quotient (HQ)**

The ratio of an exposure level by a contaminant (e.g. maximum concentration or dose) to a screening value selected for the risk assessment for that substance (e.g. RfD, NOAEL, or LOAEL). If the

exposure level is higher than the toxicity value, then there is the potential for risk to the exposed population.

### **Ingestion**

The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

### **Intermediate duration exposure**

Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

### **K<sub>p</sub>**

Dermal permeability coefficient of a compound in water. Expressed in units of centimeter of skin per hour of exposure time.

### **L/day**

Liter per day. Unit used to express drinking water ingestion.

### **L/hr**

Liter per hour. Unit used to express incidental ingestion of water while swimming.

### **Lowest-observed-adverse-effect level (LOAEL)**

The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

### **Maximum Contaminant Level (MCL)**

The maximum level of certain contaminants permitted in drinking water supplied by a public water system as set by EPA under the federal Safe Drinking Water Act. MCLs ensure that drinking water does not pose either a short-term or long-term health risk. EPA sets MCLs at levels that are economically and technologically feasible.

### **mg/kg**

Milligram (substance) per kilogram (tissue weight). Unit used to express contaminant concentration within an organism's tissue.

### **mg/kg/day**

Milligram of substance per kilogram of body weight per day. Unit used to express exposure dose.

### **mg/L**

Milligram (substance) per liter (water). Unit used to express contaminant concentration in water. 1 mg/L = 1000 µg/L.

**No-observed-adverse-effect level (NOAEL)**

The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

**Point of exposure**

The place where someone can come into contact with a substance present in the environment [see exposure pathway].

**Population**

A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

**Reference dose (RfD)**

An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

**Route of exposure**

The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

**Tolerance**

Permissible residue level for pesticides in raw agricultural produce and processed foods. Whenever a pesticide is registered for use on a food or feed crop, a tolerance must be established. EPA establishes the tolerance levels, which are enforced by the Food and Drug Administration and the Department of Agriculture.

**µg/L**

Microgram (substance) per liter (water). Unit used to express contaminant concentration in water.  $1000 \mu\text{g/L} = 1 \text{ mg/L}$ .

**Uncertainty factor**

Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].