

4.0 General Description of Renovate® and its Active Ingredient Triclopyr

4.1 General Description of Renovate® and its Formulations

Renovate® 3 is an aquatic herbicide labeled for control of floating, emersed, or submersed aquatic plants in and around aquatic sites such as ponds, lakes, reservoirs, non-irrigation canals, ditches, marshes and wetlands. Renovate® 3 is composed of 44.4% active ingredient, triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid triethylamine salt), and 55.6% "inert" ingredients. "Inert" ingredients include ethanol, triethylamine. Triclopyr is a synthetic plant growth hormone (auxin) that interferes with plant metabolism and allows selective control of woody and broadleaf species (Swadener, 1993). In aquatic ecosystems, this differential response gives triclopyr the ability to remove milfoil and allow non-invasive native monocots and tolerant dicots to proliferate (Antunes-Kenyon and Kennedy, 2004).

Renovate® 3 has been accepted for registration in the State of New York as of July 19, 2006 (see Appendix A). This registration represents a major change in labeling for the active ingredient triclopyr triethylamine salt from terrestrial uses under the Garlon 3A® label, to aquatic uses under the Renovate® 3 label. The Renovate® 3 formulation is sold to SePRO for distribution by the Garlon 3A® manufacturer Dow AgroSciences. As noted above, SePRO is also seeking registration in New York state for the USEPA approved Renovate® OTF formulation (see Appendix A).

4.2 Description of Use

Renovate® 3 is labeled for use in lakes, ponds, reservoirs, non-irrigation canals or ditches, marshes, wetlands, and transitional areas adjacent to aquatic sites. Renovate® 3 can be applied to aquatic macrophytes through surface applications from a backpack sprayer, boat, helicopter, spray boom, handgun or other suitable equipment or through sub-surface applications from a boat-mounted distribution system. Applications to terrestrial sites near wetlands can be accomplished via surface applications from a backpack sprayer or vehicle, or directly to individual woody plants through injections or cuts through the bark. The use of mistblowers is not recommended nor may applications be made via chemigation.

4.2.1 Typical Application Methods

Application of Renovate® 3 for the control of a submerged weed like Eurasian milfoil in a pond or lake could consist of either a surface or sub-surface application. For treatment of emergent and floating-leaved species, foliar applications are also conducted. Finally, pending registration with New York, application of Renovate® OTF flakes to deliver the herbicide more effectively to plants growing at depth will also be possible. The application rate would be selected based on the rate chart presented on the product label (see Appendices A and E). Additional details are provided in Section 4.4.3.

4.2.2 Rapid Response

Renovate® 3 has the potential to kill nuisance weeds with only one or two foliar applications. Bending and twisting of leaves and stems is evident almost immediately after application. Delayed symptom development includes root formation on dicot stems, misshapen leaves, stems, and flowers, and abnormal roots. Symptoms are evident on new growth first. Pigment loss (yellow or white), stoppage of growth, and distorted new growth are typical symptoms. Most injury appears in the period of several days to weeks (USEPA, 1998; Purdue, 1996). Following application to Eurasian watermilfoil, chlorotic apices were noted in three days, defoliation and sinking to the sediment surface within 14 days, and necrosis occurring over the next two weeks (Poovey et al., 2004).

4.3 Mode of Action/Efficacy

The mode of action is the overall manner in which an herbicide affects a plant at the tissue or cellular level. Herbicides with the same mode of action will have the same translocation (movement) pattern and produce similar injury symptoms (Purdue, 1996). Triclopyr, along with other herbicides such as clopyralid, fluroxypyr, and picloram, is classified as a picolinic acid (Purdue, 1996). This type of herbicide kills the target weed by mimicking the plant growth hormone auxin (indole acetic acid), and when administered at effective doses, causes uncontrolled and disorganized plant growth that leads to plant death (Tu, et al., 2001). The symptoms typical of auxin mimic herbicides include bending and twisting of stems and petioles, stem swelling (particularly at nodes) and elongation, and leaf cupping and curling.

As a systemic herbicide, killing the entire plant including the roots, triclopyr will generally provide longer efficacy than contact aquatic herbicides, such as endothall, which leave roots alive to regrow (Antunes-Kenyon and Kennedy, 2004). Triclopyr's auxin-type herbicidal activity generally controls woody and broadleaf species while most grasses and other monocots are tolerant (WSSA, 2002; Table 4-1). In contrast, broad-spectrum herbicides kill most, if not all plants, if the dosage is appropriate. Broadleaf herbicides generally kill dicot plants with broad leaves but there are exceptions; some broadleaf herbicides can kill monocots with broad leaf morphology and certain "narrowleaf" (i.e., dissected leaf) dicots are not harmed at concentrations that typically kill broadleaf plants. In aquatic ecosystems, triclopyr treatments exhibit a differential response between monocots and dicots, which generally allows non-susceptible native monocots and tolerant dicots to proliferate while effectively removing susceptible dicots, including Eurasian watermilfoil. However, there are exceptions to this generalization and it is considered in detail below.

Field evaluations with Renovate® 3 have confirmed monocots such as *Phragmites* and American frogsbit, can be controlled with foliar treatments (at labeled rates) where as cattails and grasses are not controlled (Table 4-2). In terms of submerged species, field evaluations have documented "narrowleaf" dicots such as coontail (*Ceratophyllum*), fanwort (*Cabomba*), bladderwort (*Utricularia* spp.) and white watercrow-foot are not controlled with labeled rates of Renovate® 3.

Various studies have shown triclopyr to be an effective herbicide for emersed, submersed and floating macrophyte control. It is highly selective and effective against susceptible submerged species (i.e., watermilfoil spp.) and floating and emersed plant species at a dose range of 0.75 to 2.5 mg/L and 2 -8 quarts per acre respectively. The actual recommended dose will vary based on target species, timing of application and site conditions (i.e., treatment plot size, dilution potential, flow).

Experimental treatments of aquatic environments (Netherland and Getsinger, 1993, Poovey et al., 2003) revealed little or no effect on many monocot naiads and pondweeds, which are among the most valued native species. In addition to these experimental field evaluations, information on the selectivity of Renovate® 3 between monocots and dicots has been confirmed and expanded in recent and ongoing operational lake treatment and aquatic vegetation control programs in the Midwest and Vermont. Results were compiled from several reports from the Indiana Department of Natural Resources (INDNR) Lake and River Enhancement (LARE) Program (available on-line at <http://www.in.gov/dnr/fishwild/lare/>), as well as from Lake Hortonia and Burr Pond in Vermont (Eichler, 2006). Species sensitivity results from a recent review (Antunes-Kenyon and Kennedy, 2004) are included in Table 4-2, which also indicates species' monocot or dicot status.

Table 4-2 indicates that for most listed dicots, relative susceptibility to triclopyr is rated at "medium" or "high", with the exceptions of the following submersed dissected leaf species (*Ceratophyllum*, *Cabomba* and *Utricularia*). For the monocots, the relative susceptibility is rated "low" with the following exceptions: *Phragmites*, arrowhead (*Sagittaria* spp.), water hyacinth (*Eichhornia crassipes*), American frogsbit (*Limnobium spongia*), and water stargrass (*Heteranthera dubia*). Moncot species exhibiting "low" susceptibility include some of the more common native species to New York lakes including common waterweed (*Elodea canadensis*), naiad species (*Najas* spp.), ten native pondweeds (*Potamogeton* spp.), and freshwater eelgrass (*Vallisneria spiralis*) (a.k.a. wild celery or tapegrass) (Table 4-2).

A laboratory study that measured the efficacy of triclopyr on Eurasian watermilfoil showed that effectiveness increased as both concentration and exposure time increased (Netherland and Getsinger, 1992). Control (defined as 85% reduction in biomass) was achieved in laboratory growth chambers with the following combinations of concentration (active ingredient) and exposure times: 0.25 ppm for 72 hours, 0.5 ppm for 48 hours, 1.0 ppm for 36 hours, 1.5 ppm for 24 hours and 2.0 and 2.5 ppm for 18 hours. Treatment at these concentrations for less than the indicated exposure times will provide less reduction in biomass. Ineffective control resulted when the following combinations of concentration and exposure times were applied; 2.5 ppm for 2 hours, 1.0 ppm for 6 hours and 0.25 and 0.5 ppm for 12 hours. Still, the exposure times at which control was achieved are far less than that necessary with fluridone, the preferred herbicide for most Eurasian watermilfoil control efforts

Application of the maximum recommended label rate (2.5 ppm acid equivalent (ae)) in 10-15 acre plots located in areas of quiescent waters which promoted extended exposure times led to excellent control of Eurasian watermilfoil for up to two growing seasons (Getsinger and Westerdahl, 1984; Getsinger et al 1997; Petty et al, 1998). Application of lower dosage rates (i.e., 0.5, 1.0, 1.5 ppm ae) in smaller plots (2.5 ac) with relatively short half-lives (2.9-4.2 hours) led to decreased but proportional reduction in Eurasian watermilfoil; with 27% reduction in frequency between pre- and post-application noted in the 0.5 ppm application, 33% reduction in the 1.0 ppm application, and 43% reduction in plots receiving the 1.5 ppm treatment (Poovey et al., 2004). Extrapolation from laboratory studies indicate that in waterbodies where effective concentrations of triclopyr of 0.5 to 1.5 ppm can be maintained for 24 hours, the amount of Eurasian watermilfoil reduction may exceed 85% (Poovey et al., 2004).

SePRO Corporation has conducted pond scale evaluations of foliar and submerged applications of triclopyr (Renovate® 3 and Renovate® OTF) targeting waterchestnut. Initial findings suggest Renovate® 3 may be an effective tool to control or growth regulate waterchestnut. Future evaluations are needed to better understand the dose rate and ability of Renovate® 3 to effectively damage waterchestnut tissue and impact the plants ability to produce viable seeds. Accordingly, SePRO has elected not to provide a recommendation for applying Renovate® 3 to control waterchestnut on the USEPA or NY Supplemental labels at this time.

4.4 Application Considerations that Maximize the Selectivity of Triclopyr

No specific conditions for triclopyr applications are described in 6 NYCRR Part 326 (Registration and Classification of Pesticides). However, any relevant general registration and classification conditions do apply. The Renovate® 3 label does recommend setback distances if the product is applied to lakes, reservoirs or ponds that contain a functioning potable water intake for human consumption (distance varies from 1,300 to over 11,500 feet and depends on application rate, number of acres treated, and type of weeds being treated; see Appendix E). The factors discussed in the following sub-sections should be considered in the application of Renovate® to ensure maximum selectivity of the product.

4.4.1 Method of Application

The method of application of Renovate® 3 should be chosen based on the target macrophyte to be controlled and the overall management objectives of the control program. As described in Section 4.2, Renovate® 3 can be applied to aquatic macrophytes through surface applications or sub-surface applications of the liquid formulation. Renovate® 3 should be applied as evenly as possible over nuisance plant zones. However, certain lake morphometrics may require application uniformly over the entire lake. This should be done to enhance the selectivity of the Renovate® 3 application. The other form of application for Renovate® 3 is through foliar application through spray treatments.

In the future (pending its New York registration), the Renovate® OTF triclopyr flake formulation may aid in achieving multi-year plant control in hydraulically challenging treatment sites (i.e., deep water, high dilution potential) for spot-management. By utilizing a dry flake carrier, triclopyr can be carried onto the target and spatially localized where plants are growing on the substrate.

4.4.2 Time of Application

It is recommended that Renovate® be applied when plants are actively growing, early spring into fall depending on target species. Eurasian watermilfoil initiates productivity and metabolic activity at an earlier time than native plants (Smith and Barko, 1990). They report that the characteristic annual pattern of growth is for the spring shoots to begin growing rapidly as soon as the water temperature approaches 15°C. Pullman (1993) notes that this growth generally occurs before most native aquatic macrophytes become active.

Utilizing an early growing season application would allow for the treatment of Eurasian watermilfoil prior to dense biomass establishment and while the remaining plant community is still dormant. Additionally, such applications would occur while the water is sufficiently cold so that recreational activities (i.e., swimming, fishing) are limited. However, due to the selective nature of Renovate® treatments can be effective in targeting susceptible species such as Eurasian milfoil throughout the growing season while protecting less susceptible monocots that would be established during a mid to late season treatment program.

4.4.3 Rate of Application

The federally registered application rates are described on the Renovate® 3 and Renovate® OTF labels included in Appendix A. Information on in-water and foliar applications are provided below. (see also NYS 24(c) Supplemental Labeling in Appendix E).

In-water application

It is expected that this will be the more common application type and applicable to both Renovate® 3 and Renovate® OTF. The target triclopyr concentration for in-water application ranges from 0.75 to 2.5 ppm ae for Renovate® 3. The target concentration for Renovate® OTF is similar to Renovate® 3 in water 4 feet deep or less. However, in water with an average depth greater than 4 feet deep, do not exceed 270 pounds of formulated Renovate® OTF per acre.

Application rates for individual treatments may be adjusted to reflect site-specific conditions such as the potential for water exchange within the treated area and for the susceptibility of the target macrophytes. Within that range, higher concentrations may be required where applications are made to smaller portions of a waterbody (i.e., shorelines, semi-protected and exposed cove or bay treatments), where a higher level of macrophyte control is desired, and where water movement will cause dilution with untreated water, based on the characteristics of an individual site. Repeat application may be necessary to control subsequent macrophyte regrowth in these areas, but it should not exceed 2.5 ppm triclopyr in a treatment area per annual growing season.

As with any aquatic herbicide treatment, selection of the application rate is subject to the management objectives, site conditions, water movement, applicator knowledge and experience and label language. As suggested by Poovey et al., (2004) and confirmed in operational Renovate® 3 treatment programs, several strategies should be considered to mitigate rapid dissipation, extend the exposure time of triclopyr and ultimately improve control (beyond seasonal) when using triclopyr as a submerged plant management tool. Therefore, the use of weighted and variable depth subsurface injection hoses is suggested when applying Renovate® 3 when targeting deep water invasive weeds to assist in providing adequate exposure of triclopyr throughout the water column. As an alternative (and pending registration with New York), the use of Renovate® OTF may be a more appropriate formulation choice in certain situations where control of target macrophytes located at depth is the objective.

Foliar application

The other major form of treatment of Renovate® 3 is through foliar application. The target application rate of Renovate® 3 for foliar applications to emergent and floating species in aquatic sites and wetlands ranges from 2 to 8 quarts per acre (1.5 to 6 lbs. ae). Higher rates are recommended when plants are mature, when the

weed mass is dense, or for difficult to control species. Repeat applications may be necessary to control regrowth or to control missed plants, but do not exceed 6 lbs. a.e. (8 quarts) of Renovate® 3 per acre per annual growing season. Additional information on foliar application is provided in the labels contained in Appendix A.

4.4.4 Species Susceptibility

Sections 3.4 and 3.5 discuss the potential target macrophytes that are expected to be susceptible to Renovate® 3. Susceptibility will be related to the concentration of Renovate® 3 in the treated water. The aquatic macrophyte species identified by the federal label as controlled by Renovate® 3 are presented in Table 2-1. Table 4-1 presents a list of the woody plants and broadleaf weeds that may also be controlled by Renovate® 3, many of which would likely be located in adjacent riparian areas. Exposure of these plants to Renovate® 3 may occur intentionally, through application to control co-located purple loosestrife, or unintentionally as a result of drift or other accidental means. Table 4-2 provides an updated summary of the susceptibility of aquatic macrophytes, as based on experimental treatments and current lake aquatic vegetation management applications.

Table 4-1 Woody Plants and Broadleaf Weeds Controlled by Renovate ® 3

Woody Plants		
alder	cascara	maples
arrowwood	ceanothus	mulberry
ash	cherry	Oaks
aspen	Chinese tallow	poison ivy
bear clover (bearmat)	chinquapin	poison oak
beech	choke cherry	Poplar
birch	cottonwood	salt-bush (<i>Baccharis</i> spp.)
blackberry	crataegus (hawthorn)	sweetgum
blackgum	locust	waxmyrtle
Brazilian pepper	<i>Maleleuca</i> (seedlings)	willow
Annual and Perennial Broadleaf Weeds		
burdock	ligodium	tropical sodaapple
Canada thistle	plantain	vetch
curly dock	smartweed	wild lettuce
elephant ear	tansy ragwort	

List obtained from Renovate® 3 label presented in Appendix A.

Table 4-2 Impact on Renovate to Common Aquatic Plants in New York

Aquatic Plant	Dicot (D) or Monocot (M)	Susceptibility
Emergent Species		
<i>Hydrocotyle</i> spp. (pennywort)	D	high
<i>Ludwigia</i> spp. (waterprimrose)	D	high
<i>Lythrum salicaria</i> (purple loosestrife)	D	high
<i>Phragmites</i> spp. (reed grass)	M	medium **
<i>Pontedaria cordata</i> (pickerelweed)	D	high **
<i>Sagittaria</i> spp. (arrowhead)	M	medium
<i>Scirpus</i> spp. (bulrush)	M	low
<i>Typha</i> spp. (cattails)	M	low
Floating Leaf Species		
<i>Brasenia schreberi</i> (watershield)	D	medium
<i>Lemna</i> spp. (duckweed)	M	low
<i>Limnobium spongia</i> (American frogsbit)	M	high
<i>Nuphar</i> spp. yellow water lily)	D	medium
<i>Nymphaea</i> spp. (white water lily)	D	medium
<i>Trapa natans</i> (water chestnut)	D	medium
Submergent Species		
<i>Ceratophyllum demersum</i> (coontail)	D	low
<i>Cabomba caroliniana</i> (fanwort)	D	low
<i>Chara</i> spp. (muskgrass)	*	low
<i>Elodea canadensis</i> (common waterweed)	M	low
<i>Egeria densa</i> (Brazilian elodea)	M	low
<i>Heteranthera dubia</i> (water stargrass)	M	medium
<i>Hydrilla verticillata</i> (hydrilla)	M	medium
<i>Myriophyllum aquaticum</i> (parrotfeather)	D	high

Aquatic Plant	Dicot (D) or Monocot (M)	Susceptibility
<i>Myriophyllum sibiricum</i> (northern watermilfoil)	D	high
<i>Myriophyllum spicatum</i> (Eurasian watermilfoil)	D	high
<i>Myriophyllum heterophyllum</i> (Variable milfoil)	D	high
<i>Megalondonta beckii</i> (water-marigold)	D	high
<i>Najas flexilis</i> (bushy pondweed)	M	low
<i>Najas guadalupensis</i> southern naiad	M	low
<i>Potamogeton amplifolius</i> (largeleaf pondweed)	M	low
<i>Potamogeton diversifolius</i> water-thread pondweed	M	low
<i>Potamogeton crispus</i> (curly-leafed pondweed)	M	low
<i>Potamogeton epihydrus</i> (ribbon-leaf pondweed)	M	low
<i>Potamogeton gramineus</i> (variable-leaf pondweed)	M	low
<i>Potamogeton illinoensis</i> (Illinois pondweed)	M	low
<i>Potamogeton natans</i> (floating leaf pondweed)	M	low
<i>Potamogeton praelongus</i> (white-stem pondweed)	M	low
<i>Potamogeton pusillus</i> (small pondweed)	M	low
<i>Potamogeton robbinsii</i> (Robbins' pondweed)	M	low
<i>Potamogeton zosteriformis</i> (flat-stem pondweed)	M	low
<i>Ranunculus longirostris</i> (white-water crowfoot)	D	low
<i>Stuckenia pectinatus</i> (Sago pondweed)	M	low
<i>Utricularia</i> spp (bladderwort)	D	low
<i>Vallisneria americanum</i> (eelgrass)	M	low

* Macro -algae

** Multiple treatments typically needed to target regrowth

4.4.5 Dilution Effects

To prevent the dilution of the herbicide from reducing efficacy, several recommendations may be made in selecting the appropriate Renovate formulation. If submersed macrophytes in lakes or reservoirs are being targeted with Renovate® 3, it is recommended that treated areas be greater than 5 acres and application rates should be targeted in the higher rate range. Mid to high rates of Renovate® OTF should be selected to obtain effective submersed macrophyte control when targeting areas of higher water exchange, deep water sites, spot treatment of small (less than 5 acre) areas in large water bodies, such as when narrow boat lanes or dock areas are being treated. Application periods should be chosen when heavy rainfall is not expected. Where possible, the efficacy may be improved by restricting the flow of water. Entire littoral zone specific applications provide the greatest opportunity for the long-term control of an invasive species and restoration of native plant communities.

4.5 Triclopyr Product Solubility

Solubility is a physical end point useful for understanding potential environmental impact. High water solubility is frequently associated with mobility and affects distribution in water and soil (WDOE, 2001). The Renovate® 3 and the Renovate OTF MSDS (Appendix A) indicate that the product is miscible in water.

In 2006, SePRO conducted a Good Laboratory Practice (GLP) trial to determine herbicide release and to evaluate use rates in a laboratory system designed to simulate herbicide dilution from a spot treatment. The properties of Renovate® OTF result in a quick release of triclopyr to obtain threshold concentrations, followed by a continual release of triclopyr to maintain sufficient exposure time. Studies indicate that within 24 hours the concentration of triclopyr acid in the water is essentially identical for both granular and liquid forms of triclopyr (i.e., concentration of triclopyr from granular formulation was greater than or equal to 99% of the concentration from the liquid formulation). The liquid formulation reached equilibrium after 1 hour and the granular formulation reached equilibrium after 6 hours (Hahn, 2006). These data indicate that the dissolution rates are similar for both liquid and flake forms of triclopyr.

4.6 Surfactants

The purpose of a surfactant is to increase the surface activity of the applied herbicide, thus reducing both the application rate and the cost of the application. Surfactants are not necessary when using triclopyr products to control submersed vegetation. The Renovate® 3 label (Appendix A) indicates that the addition of a nonionic surfactant to the spray mixture is recommended to improve control of floating and emerged weeds (e.g., waterhyacinth, purple loosestrife). The surfactant manufacturer's label should be consulted for the appropriate application rate and any relevant precautions.

Care should be taken to select a surfactant that has been approved for aquatic use since these products will not harm resident fish or aquatic invertebrates. Some common surfactants used with aquatic herbicides are CideKick®, X-77®, PolyControl® and SunWet® (WDOE, 2001).

4.7 Fate of Triclopyr in the Aquatic Environment

As stated previously, the active ingredient in Renovate® 3 is triclopyr triethylamine salt (TEA). Triclopyr TEA is highly soluble in water and dissociates in less than a minute to the triclopyr acid/anion and triethylamine. In aquatic conditions triethylamine is stable (half-life of 14 to 18 days) and then proceeds to rapid microbial degradation to carbon dioxide. However, triethylamine is stable to degradation under anaerobic aquatic conditions (half-life > 2 years). Because of the rapid microbial degradation under aerobic conditions, it is not expected that volatilization, photodegradation, or bioaccumulation in fish will contribute significantly to the dissipation of triethylamine (USEPA, 1998). Triclopyr acid is a weak acid which will dissociate completely to the triclopyr anion when the pH is greater than 5 (dissociation constant $pK_a = 2.93$). Therefore, the triclopyr anion will be the predominant moiety present in the environment when products containing triclopyr TEA are used (USEPA, 1998).

Laboratory tests and field dissipation studies indicate that aquatic photolysis and microbial breakdown are significant degradation pathways for triclopyr (Green and Westerdahl, 1989). Dissipation half-lives of triclopyr in water range from 0.5 days to 7.5 days due to photolysis, microbial action, and dilution. In sediment, triclopyr dissipation rates ranged from 2.8 to 5.8 days in field studies. Triclopyr is, however, persistent under anaerobic aquatic conditions. It is highly water soluble and is not expected to bind with organic materials (Antunes-Kenyon and Kennedy, 2004).

4.7.1 Water

Laboratory tests show that aquatic photolysis is a significant degradation pathway for triclopyr (Woodburn et al., 1990). Field dissipation studies indicate that microbial mediated degradation is also important (Antunes-Kenyon and Kennedy, 2004). Photodegradation of triclopyr acid was rapid; the half-life was less than 1 day in sterile solutions and approximately 1 day in natural water. The major photodegradation product observed in sterile solutions was 5-chloro-3,6-dihydroxy-2-pyridinoloxycetic acid (TCP); oxamic acid was the major degradation product in natural river water (USEPA, 1998). TCP has been shown in laboratory experiments to decompose rapidly upon exposure to UV radiation (half-life 25 min) producing carbon dioxide and many degradation products (Feng, et al., 1998).

Triclopyr acid photodegraded in sterile aqueous buffered solutions (pH 7) with half-lives of 0.6 days (8-9 hours) using natural light (August in Michigan) and 0.36 days using filtered mercury lamps (samples irradiated continuously). The half-lives in river water using natural and artificial light sources were 1.7 and 0.7 days, respectively. Triclopyr acid did not degrade in similar solutions incubated in the dark for up to 3 days. Identified degradates in both sterile solutions and river water were TCP and oxamic acid; TCP was the major degradate in the sterile solutions (up to 48% of the applied), while oxamic acid predominated in the river water (up to 16% of the applied) (USEPA, 1998).

Another metabolite, 3,5,6-trichloro-2-methoxypyridine, or TMP, may also be produced during the derogation of triclopyr acid. It is uncertain whether TMP is a direct degradate of triclopyr, TCP, or both (Petty, et al., 2003).

Laboratory testing suggests that in the absence of light due to murky natural water, direct shading, or floating vegetation mats, the degradation of triclopyr by microbial action would be quite slow, producing the metabolites TCP and TMP only after several months. In addition, chemical hydrolysis would not be a major route of triclopyr degradation. However, the evidence from field studies examining triclopyr dissipation in natural waters seems to contradict these laboratory studies. Field studies indicate that triclopyr in natural waters degrades rather quickly, but at least partially independent of the action of direct photolysis. Applications of triclopyr at the surface of the water or at the subsurface below dense plant mats yielded similar dissipation half-lives, with TCP and TMP being the major degradation products.

It appears that in open systems, water exchange is the most significant factor affecting the predicted dissipation of triclopyr. Triclopyr applied to enclosed systems (ponds) degraded at a predictable rate, regardless of geographic location and light intensity, producing TCP and TMP at predictable levels. This would suggest that a major mechanism for the removal of triclopyr from the aquatic environment is microbial degradation, though the role of photolysis likely remains important in near-surface and shallow waters (Petty, et al., 2003).

4.7.1.1 Aerobic

Triclopyr acid degraded slowly (half-life of 142 days) in a silty clay soil; water system incubated aerobically for 30 days. The only degradate observed was TCP at <5% of the amount applied at 30 days; however, the study was not conducted for a sufficient duration to adequately describe the formation and decline of the degradate TCP. The re-registration document indicated that additional information on the aerobic aquatic metabolism of TCP was required (USEPA, 1998).

4.7.1.2 Anaerobic

Triclopyr acid was persistent under anaerobic conditions in two sandy loam soils incubated anaerobically (flooding plus nitrogen) for 30 days prior to pesticide addition. Triclopyr acid levels decreased to approximately 80% of the applied portion after 365 days. A half-life of 1300 days was calculated from this study. However, confidence in this value is limited because of the extrapolation outside the duration of the study. The only identified degradate was TCP at maximum concentrations of approximately 25% of the original applied level at 365 days post-treatment (USEPA, 1998).

4.7.2 Sediment

The high water solubility of triclopyr acid (430 ppm) along with its partition coefficient values indicate that both triclopyr (K_{oc} 27mg/L) and the degradation product TCP (K_{oc} 151 mg/L) are likely to be mobile in soil and not adsorb to organic materials or sediment (Antunes-Kenyon and Kennedy, 2004). In terrestrial studies, triclopyr was moderately persistent, with persistence increasing as it reaches deeper soil levels and anaerobic conditions (USEPA, 1998). In terrestrial field dissipation studies, low concentrations of triclopyr were found at soil depths of up to 45 cm, however triclopyr did not persist at this depth (Antunes-Kenyon and Kennedy, 2004).

While triclopyr is persistent in anaerobic aquatic environments, it is not found to persist in sediment in field dissipation studies. Based on these studies, the dissipation rates for triclopyr ranged from 2.8 days in a pond in Columbia, Maryland to 5.8 days in Lake Minnetonka, Minnesota. The metabolite TCP also dissipates quickly from the sediment (half-lives ranged from 3.8 days to 13.3 days) (Antunes-Kenyon and Kennedy, 2004).

Based on adsorption/desorption studies using sand, sandy loam, silt loam, and clay loam soils, unaged triclopyr acid, aged triclopyr acid (15 and 30 days aging period), and the degradate TCP were all very mobile. Adsorption was not correlated with cation exchange capacity or organic carbon content. Adsorption of triclopyr was found to be extremely low and reversible with soil adsorption coefficients typically much lower than 1.0 L/Kg (typical range 0.012 to 1.7 L/Kg) (USEPA, 1998).

4.7.3 Aquatic Dissipation

The aquatic dissipation half-lives observed in the field are consistent with the shorter half-lives observed in the photolysis in water studies. In general, results of the available studies suggest that triclopyr acid is rapidly dissipated under aquatic conditions in the field (half-lives ranged from 0.5 to 3.5 days in Lake Seminole, Georgia). Some factors that could affect the rate of dissipation in cases where aqueous photolysis is an important dissipation factor include vegetative cover, type of vegetation, depth of the plot, and suspended sediment (USEPA, 1998).

Triclopyr acid (applied as the TEA salt at 27-30 lb ae/A) dissipated with calculated half-lives of 0.5 and 3.5 days in the surface waters of 10-acre plots located in the Spring Creek arm of Lake Seminole, Georgia, following surface and aerial applications, respectively. The plots were approximately 65-75% covered with vegetation at time of application. The degradate TCP was detected at 0.06-0.18 ppm in surface (1-foot depth) and bottom (3 feet above the bottom) waters 1 to 8 hours after application, but was not detected (<0.05 ppm) in surface or bottom water after 1 day post-treatment. Triclopyr was detected at up to 0.64 ppm in the sediment layer (up to 5-10 cm deep) immediately post-treatment, but was <0.10 ppm (detection limit) at all other sampling intervals. TCP was not detected in the sediment (<0.05 ppm) at any interval (USEPA, 1998).

4.7.4 Bioaccumulation/Biomagnification

The re-registration document for triclopyr indicates that the requirement for fish and non-target organism bioaccumulation studies was waived for triclopyr TEA due to its low octanol/water partition coefficient ($K_{ow}<5$). Information contained in supplemental studies showed that only slight bioaccumulation (<10x) was observed for triclopyr acid and its degradate TCP (USEPA, 1998).

4.8 Triclopyr Residue Tolerances

The registration of Renovate® 3 for aquatic use in ponds, lakes, reservoirs, and in non-irrigation canals or ditches, was granted after the completion of the 1998 Re-registration Eligibility Decision (RED) (USEPA, 1998), therefore the RED does not consider these uses. The RED considered uses on rice, rangeland and pasture, rights-of-way, forestry and turf, including home lawns, for control of broadleaf weeds and woody plants. At the time of re-registration there were 12-registered products containing triclopyr butoxyethyl ester (BEE) and 24 products containing triclopyr TEA (the active ingredient in Renovate® 3). The Agency determined that all uses, when labeled and used as specified in the RED, were eligible for re-registration (Antunes-Kenyon and Kennedy, 2004).

In establishing or reassessing tolerances, the Food Quality Protection Act of 1996 (FQPA) requires the EPA to consider aggregate exposures to pesticide residues, including all anticipated dietary exposures and other exposures for which there is reliable information, as well as the potential for cumulative effects from a pesticide and other compounds with a common mechanism of toxicity. The Act further directs EPA to consider the potential for increased susceptibility of infants and children to the toxic effects of pesticide residues, and to develop a screening program to determine whether pesticides produce endocrine disrupting effects (USEPA, 1998).

The 1998 RED considered only dietary and drinking water exposure in the aggregate assessment, since other non-occupational exposures to triclopyr were expected to be minimal. EPA uses residue chemistry data to estimate the exposure of the general population to pesticide residues in food and for setting and enforcing tolerances for pesticide residues in food or feed.

Triclopyr tolerances are established for the combined residues of the parent triclopyr acid and its metabolites TCP and TMP in or on the following raw agricultural commodities (40 CFR § 180.417(a)):

- Grass, forage – 500 ppm
- Fish – 3.0 ppm¹
- Shellfish – 3.5 ppm¹

Tolerances are also established for the combined residues of only the parent triclopyr acid and its metabolite TCP in or on the following raw agricultural commodities (40 CFR § 180.417(b)):

- Meat, fat, and meat byproducts (except liver and kidney) of cattle, goats, hogs, horses, and sheep – 0.05 ppm
- Liver and kidney of cattle, goats, hogs, horses, and sheep – 0.5 ppm
- Milk – 0.01 ppm
- Rice, grain – 0.3 ppm
- Rice, straw – 10.0 ppm
- Eggs – 0.05 ppm
- Meat, fat, and meat byproducts (except kidney) of poultry – 0.1 ppm

Temporary tolerances were also presented in the re-registration document (USEPA, 1998) for the parent triclopyr acid and its metabolite TCP in or on the following commodities:

¹ Updated in Federal Register Volume 67 Number 181 September 18, 2002 (USEPA, 2002).

- Fish – 0.2 ppm
- Shellfish – 0.2 ppm
- Water, potable – 0.5 ppm

Renovate® 3 is not registered for use on any agricultural commodities. Although the labeling does not bear any restrictions on fishing or livestock consumption of water from the treatment area, no significant contributions to dietary exposure are expected from the use of Renovate® 3. The following product label prohibitions mitigate much of the potential for additional residues of triclopyr in or on agricultural commodities:

- Prohibition for application via any irrigation system;
- Prohibition on applications where runoff water may flow onto agricultural land; and
- Prohibition on the use of treated water for irrigation until 120-days following application or until non-detectable by laboratory analysis (immunoassay) (Antunes-Kenyon and Kennedy, 2004).