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Low-Dose Metering of Endothall for Aquatic Plant Control in Flowing Water

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ABSTRACT

Endothall (7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid) applied as Aquathol K[R] at a target rate of 0.4 mg/L for 84 hr was evaluated in two high-flow canals located in Idaho and Colorado in the late summer of 1996 against the nuisance species sago pondweed *(Potamogeton pectinatus* L.). A prototype metering pump was developed by U.S. Bureau of Reclamation personnel to deliver a constant low dose of herbicide in response to the variable flow rates often experienced in these canal systems. Residue analyses indicated that target herbicide rates were closely approximated through 84 hr in the Idaho study, with a resultant 97% reduction of sago pondweed biomass along the 1.6-km treatment site at 28 days posttreatment. In contrast, biomass at untreated control sites remained near pretreatment levels of 120 g dry weight/m^2. Target endothall concentrations were maintained through 55 hr at the Colorado site, followed by an unexplained drop in endothall levels to one half the target concentration through 84 hr. Biomass reductions of 60 to 98% were recorded along the 5.3 km treatment site by 17 days posttreatment. Results demonstrated that the low-dose, extended exposure concept for endothall treatment was efficacious and logistically feasible. In addition, the newly developed metering pump may have great utility for herbicide application in high-flow environments of the western United States.

Key words: aquathol, aquatic herbicide, *Potamogeton pectinatus,* Sago pondweed, aquatic weed control.

INTRODUCTION

Aquatic plants can severely restrict water flow in delivery channels carrying agricultural, industrial, municipal, and recreational waters. In the western United States, traditional chemical control techniques have included the use of rapid acting contact biocides such as acrolein (2-propenal) and xylene (Anderson 1990); however, increased concern over toxicity of these products to fish and wildlife in waters managed by the U.S. Bureau of Reclamation (Reclamation) has led to an interest in alternative chemical control methods. Although use of other herbicides may lessen concerns over toxicity, traditional slug or surface applications of many of these compounds may not be efficacious in canals due to rapidly dissipating concentrations and a concomitant lack of exposure period (Hansen et al. 1983). Concentration and exposure time studies conducted in the laboratory and in large outdoor hydraulic flumes have demonstrated that delivery of the herbicide endothall at concentrations of 8 to 10% (0.4 to 0.5 mg/L) of the maximum label rate (5.0 mg/L) over an extended exposure period can be efficacious for control of nuisance aquatic vegetation (Netherland et al. 1991, Netherland et al. 1994). Endothall applied as the Aquathol K formulation has low potential for fish and wildlife toxicity even at the maximum use rate of 5.0 mg/L (Elf Atochem[3]). Based on this information, a pilot study was conducted in Idaho in 1994 to determine the feasibility and potential logistical problems associated with applying low doses of endothall (applied as Aquathol K) for sago pondweed control in a western irrigation system[4]. The ability of sago pondweed to thrive in high-flow environments and form a surface canopy that impedes water flow, makes it a particularly troublesome plant in the western United States. A good review of the ecology, biology and early methods used for control of sago pondweed in the Pacific Northwest is provided by Yeo (1965).

Pilot study results[4] were marginal in terms of significant biomass reduction of sago pondweed. Problems with responding to the highly fluctuating canal flow rates by continuous manual adjustment of the metering equipment prevented maintenance of the target endothall concentration of 0.4 mg/L for 96 hr. Despite the problems with achieving target rates, the endothall treatments did result in the removal of the sago pondweed canopy within 1 week after treatment, and project managers were generally pleased with the efficacy results through 42 days posttreatment. The conclusions of this study were that the low dose extended exposure concept was feasible and could be efficacious; however, significant improvement in the delivery system would be required to make this strategy practical. In response to problems encountered during the 1994 study, Reclamation developed an automated metering system that maintains the desired herbicide concentration in linear-flow systems with fluctuating flow rates. This system was designed for use at remote sites, is totally portable, and can be operated using solar power. This new pump will significantly reduce manpower requirements and the lag time associated with manually

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[3]Elf Atochem, 1992. Review of the effects of endothall products on aquatic ecosystems

[4]Sisneros, D. and E. G. Turner. 1996. Reduced rate endothall application for controlling sago pondweed in high-flow environments: Summary of 1994 study. Technical Memorandum 8220-96-12. U.S. Department of Interior, Bureau of Reclamation. 5 pp.

adjusting metering pumps following flow rate measurements.

Two metering studies using low concentrations and extended exposure periods were conducted by Reclamation to evaluate the automated metering system and to determine the efficacy of metering low concentrations of the herbicide endothall (i.e at rates approaching 8% of the maximum label rate) to control sago pondweed in flowing water.

MATERIALS AND METHODS

Idaho Site

A field site was selected in Reclamation's Pacific Northwest Region, in the Minodoka Project on land operated and maintained by the North Side Canal Company, Jerome, ID. Treatments were conducted on the S-19 canal from August 6 to August 9, 1996. The portion of the S-19 canal used for this study carries return flow irrigation water (waste water) and is approximately 10 miles southwest of Wendall, ID.

This earth lined canal is approximately 3 to 4 m wide and 0.7 to 1.0 m deep. Flows in the system during the study ranged from 145 to 285 l/sec (5.1 cubic feet per second (cfs) to 10 cfs) with linear velocities of approximately 0.5 m per second. The length of canal treated by the upstream injection of herbicide was approximately 1.7 km. Below this point, dilution from the inflow of the W-9 canal further diluted endothall concentrations. The combined flows from both canals continued for 3.2 km to a pond of 1.3 ha. Here additional flows from another canal further diluted any treated water prior to discharge into the Snake River, approximately 2.4 km downstream of the pond.

Four plant biomass sampling sites (30.5 m long) were located within the 1.7 km treatment area to determine herbicide efficacy. One untreated biomass sampling site was selected 200 m above the application point. Sampling sites were selected in areas with high densities of plants (visual observations) between the application site and sampling site 5 at 1.2 km downstream.

Nine random shoot biomass samples were taken from each of the biomass sampling sites using a 0.25 m square frame prior to treatment and at 28 days after treatment (DAT). Biomass samples were then sorted to species and dried at 100 C for 24 hr to a constant weight. The major weed species was sago pondweed with small amounts of *Alisma* sp. L. (water plantain). Shoot biomass data from each sample site were subjected to analysis of variance (ANOVA) and means compared to the untreated controls using Dunnet's test at $\alpha = 0.05$. In addition, t-tests ($\alpha = 0.05$) were used to compare pretreatment biomass to biomass at 28 DAT within each sampling site.

Six water sampling sites were established for endothall residues downstream of the herbicide application site. Untreated control water samples were taken immediately upstream of the herbicide application site. Water samples were collected at 200, 411, 500, 586, and 1600 m from the application site and from Lemon Power Plant (3800 m), which received water from the treated canal for use in power production prior to discharge into the Snake River, ID. Duplicate water samples were collected from each of the six water sampling sites at pretreatment, 7, 12, 28, 36, 48, 60, 72 and 84 hr posttreatment. Water samples were collected from mid-depth, and frozen as soon as possible to reduce herbicide degradation prior to analysis. To date, residue analyses have been completed for sites 2 (411 m) and 4 (586 m), the untreated control, and Lemon Power Plant.

The dipotassium salt of endothall (Aquathol K) was applied to the S19 canal at a rate of 0.4 mg/L for 84 hr using an automated delivery system which is currently patent pending. This system is portable, solar powered, and allows realtime adjustment of delivery of herbicide to the canals.

Colorado Site

A field site was also selected in Reclamation's Great Plains Region on land operated and maintained by the Farmers Independent Ditch Company (FIDCO), Gilcrest, CO. The FIDCO canal is earth lined and approximately 3.1 m wide and 0.7 m deep. Flows measured at check structures and gauging stations ranged from 74 to 327 l/sec (2.22 cfs to 9.81 cfs) with linear velocities of 0.5 m/sec. The length of the canal which was treated was approximately 5.3 km and this water was subsequently diverted to a 1.3 ha augmentation pond for recharging ground water during the study.

Five biomass sampling sites (30.5 m long) were located within the 5.3 km area to determine endothall's efficacy on sago pondweed. In addition, one untreated control biomass sampling site was located upstream of the application site. Biomass sampling sites were selected in areas with high densities of plants (visual observations) between the application site and 5.3 km downstream.

Nine random shoot biomass samples were taken from each of the biomass sampling sites using a 0.25 m square frame prior to treatment and at 17 DAT. Biomass samples were then sorted to species and dried at 70 C for 48 hr to a constant weight. The major aquatic weed species was sago pondweed. Shoot biomass data from each sample site were subjected to analysis of variance (ANOVA) and means compared to the untreated controls using Dunnet's test at $\alpha = 0.05$. In addition, t-tests ($\alpha = 0.05$) were used to compare pretreatment biomass to biomass at 17 DAT within each sampling site.

Six water sampling sites were established for endothall residues at 800, 1600, 2400, 4000, and 5300 m downstream of the herbicide application site. Untreated control water samples were taken immediately upstream of the herbicide application site in the control biomass sampling site. Duplicate water samples were collected from each of the six water sampling sites at pretreatment, 6, 12, 24, 36, 48, 55, 72, 84 and 96 hr posttreatment. Water samples were collected from mid-depth, and frozen as soon as possible to reduce herbicide degradation for analysis.

Endothall applied as Aquathol K was metered in to the FIDCO canal from September 23, 1996 to September 28, 1996, at a target rate of 0.4 mg/L for 96 hr using the automated delivery system described above.

RESULTS AND DISCUSSION

Idaho Site

Residue analyses indicated that the projected target rate of 0.4 mg/L (endothall) for 84 hr was closely approximated

(Figure 1). Endothall residues for the treatment sites in the canal were approximately 0.30 mg/L or greater and were maintained for 84 continuous hours. Concentrations of approximately 0.40 mg/L were noted at 7, 24, and 72 hr posttreatment while residues of 0.30 or greater were noted at the 12, 36, 48 60 and 84 hr posttreatment sampling. Some loss of endothall is to be expected due to degradation, sorption, and uptake, and the maintenance of rates near the target concentration was considered successful. As metering was discontinued, residues in the treatment sites fell to near 0 mg/L by 96 hr posttreatment. Concentration of less than 0.2 mg/L (the acceptable residue level for drinking water of 0.2 mg/L) were noted in Lemon Power Plant water which eventually flows into the Snake River. Residues in the untreated control were near 0 mg/L throughout the sample period.

Following endothall treatment, sago pondweed and water plantain were significantly reduced by the 28 day posttreatment sampling (Figure 1). Pretreatment biomass ranged from 30 to 150 g dry weight/m^2 whereas at 28 DAT biomass ranged from 120 g dry weight/m^2 for the untreated control site to 0 to 2 g dry weight/m^2 for the treated sites. Visual assessments by Northside Canal operational personnel suggested that sago pondweed recovered to about 30% of the pretreatment levels during the remainder of the growing season, but was not considered to be at problematic levels.

Colorado Site

Residue analyses indicated that endothall concentrations ranged from 0.27 to 0.35 mg/L for 55 hr through the entire 5.3-km length of canal (Figure 2). After the 55-hr sampling, residues at all sampling sites dissipated to approximately 0.2 mg/L for the duration of the study (84 hr). Some discrepancies in residue analysis were noted in duplicate water samples which may account for the variability observed at 36, 48 and 55 hr. While the inability to achieve exactly the target concentration of 0.4 mg/L was not surprising, due to previously described factors, the decrease in residues at 55 hr remains unexplained. Based on the loss of residue after 55 hr, it must be assumed that either flow rates increased without a concomitant increase in delivery rate, or the delivery rate slowed without a decrease in flow. Regardless of these possibilities, this represented the initial phase of testing of the new metering pump and results were generally quite positive. The pump is still in the research phase and will require some development and refinement by Reclamation personnel prior to routine operational use in the field.

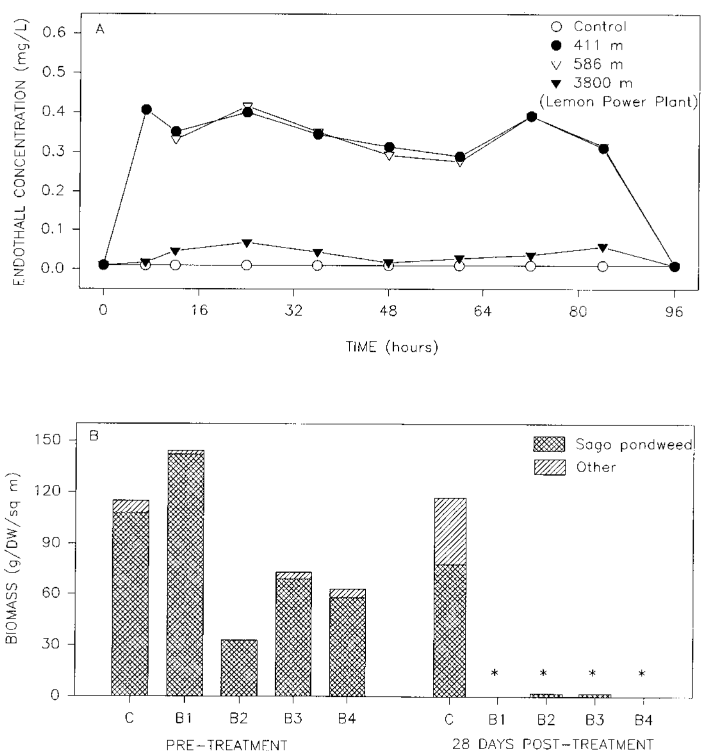

Figure 1. (A) Endothall residues at four sites in the S19 Canal in Idaho following metered injection at a target rate of 0.4 mg/L for 84 hr. Each value represents the mean of duplicate samples. (B). Sago pondweed biomass at pretreatment and 28 days posttreatment collected at 5 sites from the S19 Canal in Idaho. Each bar represents the mean of 9 samples. Asterisks above the bars at 28 days posttreatment indicate that biomass at sampling sites B1-B4 was significantly different from the untreated control at 28 DAT (Dunnet's test at $\alpha = 0.05$) and was also significantly different from pretreatment biomass values (t-test, $\alpha = 0.05$).

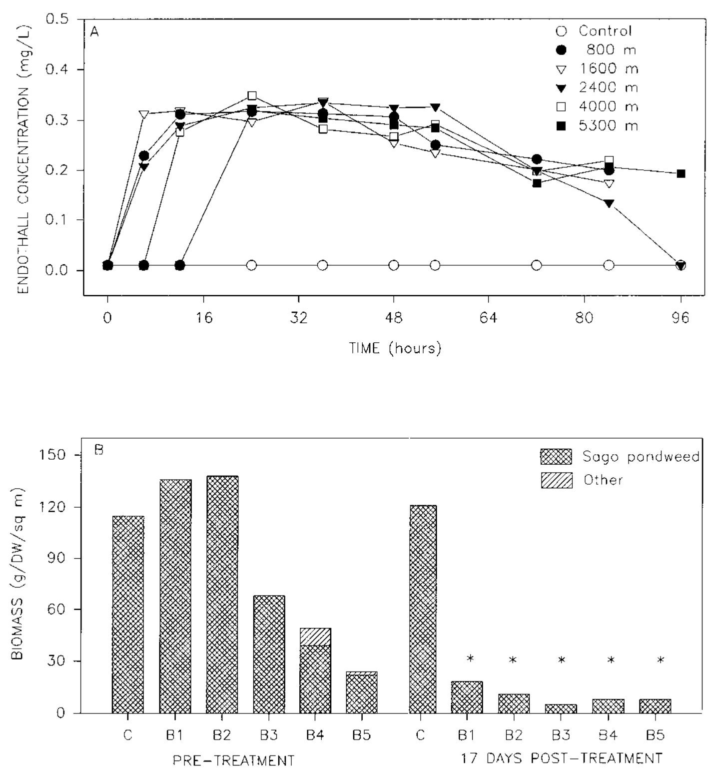

Figure 2. (A) Endothall residues at six sites in the FIDCO canal in Colorado following metered injection at a target rate of 0.4 mg/L for 84 hr. Each value represents the average of duplicate samples. (B). Sago pondweed biomass at pretreatment and 17 days posttreatment collected at 6 sites from the FIDCO canal in Colorado. Each bar represents the average of 9 samples. Asterisks above the bars at 28 days posttreatment indicate that biomass at sampling sites B1-B4 was significantly different from the untreated control at 28 DAT (Dunnet's test at $\alpha = 0.05$) and was also significantly different from pretreatment biomass values (t-test, $\alpha = 0.05$).

Despite lower than targeted endothall concentrations, sago pondweed was significantly reduced by the 17 DAT sampling (Figure 2). Pretreatment biomass ranged from approximately 25 to 137 g dry weight/m^2, whereas biomass at 17 DAT was 115 g dry weight/m^2 for the untreated control site and ranged from 4 to 20 g dry weight/m^2 for the treatment sites. The late fall treatment, and the fact that these canals were subsequently dewatered, precluded further evaluation of sago pondweed regrowth.

Both the Idaho and Colorado studies demonstrated that delivery of low concentrations of Aquathol K (0.3 to 0.4 mg endothall/L) for 84 continuous hours can effectively control sago pondweed. Based on laboratory information per concentration and exposure time relationships, surface applications of higher rates of endothall (3.0 to 5.0 mg/L) along the length of these canals would not have been effective due to inadequate exposure periods. In addition, off-target movement of these higher residue levels could cause concern where fish, wildlife and potable water are issues. Current irrigation restrictions on the Aquathol K product (7 day restriction at the rates applied) would have to be substantially reduced for the low concentration/extended exposure strategy to find widespread use in Reclamation managed waters; however, dissipation studies to generate the type of data required for label changes are currently planned by the manufacturer.

The delivery pump developed by Reclamation significantly reduced manpower requirements compared to earlier conventional applications and required no maintenance or calibration during the study. Due to the development of this pump, the strategy of delivering low doses of herbicide over time is considered to be quite feasible from an operational standpoint. Although still in the development stage, this pump has excellent potential for precision delivery of herbicides in linear flow systems. The ability to deliver such defined doses should spur future concentration and exposure time studies with several classes of herbicides to determine the minimum rates and exposures necessary for control of a given nuisance species.

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