REC-ERC-76-11

RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT *Salmo gairdneri*

Engineering and Research Center
Bureau of Reclamation
Joint Report with
Fish and Wildlife Service and
Agricultural Research Service

January 1977

MS-230 (8-70)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. REC-ERC-76-11	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Residues of Emulsified Xylene in Aquatic Weed Control and Their Impact on Rainbow Trout, *Salmo gairdneri*		5. REPORT DATE January 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D. F. Walsh, J. G. Armstrong, T. R. Bartley, H. A. Salman, and P. A. Frank		8. PERFORMING ORGANIZATION REPORT NO. REC-ERC-76-11
9. PERFORMING ORGANIZATION NAME AND ADDRESS Engineering and Research Center Bureau of Reclamation Denver, Colorado 80225		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. 13. TYPE OF REPORT AND PERIOD COVERED
12. SPONSORING AGENCY NAME AND ADDRESS Same		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Emulsified xylene is used to control aquatic weeds in irrigation systems which may occasionally return irrigation water to aquatic habitats that maintain trout populations. Laboratory studies were conducted to determine effects of xylene on rainbow trout, *Salmo gairdneri*, and to measure dissipation of xylene residues in irrigation waters as treated water flowed through canals, irrigated fields, and into return flows.

Rainbow trout exposed to emulsified xylene for 2 hours survived a concentration of 7.1 p/m (parts per million), but suffered 100 percent mortality at 16.1 p/m. An off-flavor was produced in fillets of rainbow trout after exposure to 7.1 p/m of xylene for 2 hours, or to 0.36 p/m for 56 days, and was dependent on concentration and exposure. Residues of xylene in fillets of rainbow trout and off-flavor was directly related. Xylene dissipated downstream in irrigation canals, from treatment concentrations of 548 to 760 p/m to an average concentration of 100 p/m or below after the water traveled 10 miles. Xylene residues dissipated in treated irrigated field waters during furrow irrigation from 150 p/m at the head ditch to less than 0.2 p/m in return flows. The xylene residues entering aquatic habitats in return flows from irrigated fields should not seriously affect fisheries or other segments of the aquatic environment.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- / *emulsifiers / *aquatic weeds / *herbicide / *aquatic weed control / *irrigation canals / *fish / mortality / off-flavor / *residues / *dispersion rate / environment / water quality / aquatic ecosystem

b. IDENTIFIERS-- / *xylene

c. COSATI Field/Group 06F COWRR: 0606

18. DISTRIBUTION STATEMENT Available from the National Technical Information Service, Operations Division, Springfield, Virginia 22151.	19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES 15
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. PRICE

REC-ERC-76-11

RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT *Salmo gairdneri*

by

D. F. Walsh

J. G. Armstrong

T. R. Bartley

H. A. Salman

P. A. Frank

January 1977

Applied Sciences Branch
Division of General Research
Engineering and Research Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION

ACKNOWLEDGMENTS

We thank V. S. Miyahara, U.S. Department of the Interior, Bureau of Reclamation, R. W. Raines and J. C. Pringle, Jr., U.S. Department of Agriculture, Agricultural Research Service, Denver, Colo., for assistance in constructing the treatment apparatus, applying the xylene treatments, and in analyzing the water samples. We also thank R. Hattrup, Bureau of Reclamation, Ephrata, Washington, Columbia Basin project, for making the xylene treatments and collecting the treated water samples.

This report was prepared jointly by:

D. F. Walsh and J. G. Armstrong, Fish -Pesticide Research Laboratory
U. S. Department of the Interior, Fish and Wildlife Service, Columbia, Mo.

T. R. Bartley and H. A. Salman, Division of General Research,
U. S. Department of the Interior, Bureau of Reclamation, Denver, Colo.

P. A. Frank, Crops Research Division, Agricultural Research Service,
U. S. Department of Agriculture, Denver, Colo.

The information in this report regarding commercial products or firms may not be used for advertising or promotional purposes, and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation, Agricultural Research Service, or the Fish and Wildlife Service.

CONTENTS

	Page
Introduction	1
Summary	1
Applications	2
Materials and methods	2
Xylene treatments to rainbow trout	2
Test facility	2
Fish	2
Xylene and emulsifier	2
Exposure	2
Analyses of xylene residues	3
Toxicity tests	6
Off-flavor analysis	6
Xylene treatments in irrigation systems	6
Test canals	6
Treatments	6
Sampling of treated water	6
Results and discussions	8
Effects of xylene on rainbow trout	8
Acute toxicity to fish	8
Behavior of fish	8
Off-flavor of fish	9
Xylene residues in fish	9
Off-flavor vs. xylene residues in fillets	9
Xylene residues in irrigation systems	12
Residues in canals	12
Residues in return flows	14
Conclusions	14
Bibliography	15

TABLES

Table		
1	Characteristics of, and treatment data for irrigation systems used to study residues of xylene in irrigation water	7
2	Characteristics of, and treatment data for laterals used to study xylene residues in return flows	7

CONTENTS—Continued

Table		Page
3	Acute toxicity of xylene, emulsified xylene (xylene plus Emcol AD-410), and Emcol AD-410, to rainbow trout	9
4	Toxicity of xylene to rainbow trout in artificial streams	9
5	Xylene residues in fillets of rainbow trout exposed to xylene	11
6	Off-flavor index and residues in rainbow trout exposed to sublethal concentrations of xylene for 56 days	12

FIGURES

Figure		
1	Aquatic weed test station, Carter Lake, Colo	3
2	Water bath and Mariotte bottle (long term)	4
3	The Mariotte bottle used to deliver predetermined volumes of emulsified xylene (long term)	4
4	Methods used to apply xylene for the 2-hour exposure	5
5	Application of emulsified xylene for control of aquatic vegetation in an irrigation canal	8
6	Off-flavor index in rainbow trout caused by exposure to sublethal concentrations of xylene for 2 hours	10
7	Off-flavor index in rainbow trout caused by exposure to sublethal concentrations of xylene for 56 days	10
8	Average residues of xylene in fillets of rainbow trout after exposure to various concentrations of xylene in water over a 56-day treatment	11
9	Dissipation of xylene in six irrigation systems	13
10	Dissipation of xylene from laterals, through crop fields, and into return flows	14

INTRODUCTION

In 1947, researchers in the Bureau of Reclamation, Agricultural Research Service Cooperative Weed Control Program at Denver, Colorado discovered that short exposures of certain emulsified aromatic hydrocarbon solvents were effective for killing the foliar portions of submersed aquatic vegetation [1][1]. Field trials showed that these solvents were effective and economical for controlling aquatic weeds in irrigation systems [2, 3]. Further studies on the chemical and physical characteristics of the most effective aromatic solvents showed that the principal active ingredient was xylene, (C_6H_4 $(CH_3)_2$). To obtain consistency in the quality of solvents purchased, a grade B xylene was eventually recommended to replace the mixtures of solvents previously used for weed control [4].

One of the early concerns about the use of aromatic solvents was the potential toxicity to crops irrigated with the treated water. Researchers at ARS (Agricultural Research Service) stations conducted studies in the western United States to determine the effects of various concentrations of xylene-treated water on several furrow-irrigated crops. The study showed that water containing xylene at the maximum concentration recommended for aquatic weed control which is 10 gallons per cubic foot per second or for 30 to 60 minutes, could be used for furrow irrigation without injury to a wide variety of crop plants. Treated water could also be used for flood irrigation if submersion of foliage is limited. Alfalfa, red Mexican beans, carrots, cotton, grain sorghum, ladino white clover, lettuce, lima beans, wheat, oats, orchardgrass, potatoes, sugarbeets, and sweet corn, crop yields were not reduced by irrigation with water containing the above concentrations of xylene. However, concentrations twice the maximum rate injured young plants.

Recently the effects of sprinkler irrigation with xylene-treated water has been tested [7] at concentrations of 370, 740, and 1,480 p/m (parts per million, by volume) xylene applied equivalent to 2 acre-inches of water to six crop plants: alfalfa, tomato, dwarf corn, squash, potato, and field beans. The 370 and 740 p/m concentrations were each applied to the crop plants three times and the 1,480 p/m concentrations and the control (untreated water) were applied once. The investigations concluded that sprinkler irrigation with xylene-treated water at these concentrations did not significantly impair the growth and development of farm crops or decrease yields.

[1] Numbers in brackets refer to the bibliography at the end of this report.

Little information was available, then, on xylene concentrations likely to be found in irrigation water at the fields and drains following its application for weed control in canals. Xylene-treated water in several canals throughout the western U.S. was monitored to determine the concentrations of xylene that remained in the water as it moved down canals and laterals, through the head ditches onto crop land, and finally into return flows.

It was also recognized during early research that xylene was extremely toxic to fish and that it was not an acceptable herbicide for use in domestic water supplies. As the volume of xylene used for aquatic weed control continued to increase, questions arose concerning its possible adverse ecological effects, in particular, the consequences of allowing xylene-treated water to enter habitats that support sport fisheries.

Little was known about the toxicological effects of either occasional brief exposures of fish to high concentrations of xylene or of prolonged exposures to low concentrations. Therefore, studies were begun in 1972 with rainbow trout, *Salmo gairdneri,* to determine the toxicity of xylene, the rate of residue uptake and elimination, and the potential effect of the chemical, causing off-flavor in fish flesh. The trout were exposed to xylene in artificial streams (flumes) at the Bureau of Reclamation Aquatic Weed-Fish Research Test Facility, Carter Lake, Colo. Results of the fish mortality test were reported at the 1974 meeting of the Weed Science Society of America [6].

SUMMARY

Rainbow trout were exposed continuously in artificial streams to average xylene concentrations of 0.36, 0.74, and 1.3 p/m for 56 days, and to 0.64, 3.6, 7.1, 16.1 and 25.6 p/m for 2 hours. All fish exposed to concentrations of 16.1 and 25.6 p/m for 2 hours were killed. The 96-hour LC_{50} (LC_{50} being the median lethal concentration as explained later) for xylene was estimated to be 13.5 p/m. Exposure to 3.6 and 7.1 p/m xylene for 2 hours caused symptoms similar to anesthesia. Recovery of the fish appeared to be complete after a short time in untreated water.

Continuous exposure of rainbow trout to xylene concentrations of 0.36, 0.74, or 1.3 p/m for 56 days caused a significant off-flavor in fillets. Degree of off-flavor was directly correlated with xylene residues as detected by gas-liquid chromatography, and disappeared within 2 or 3 days after the fish were placed in untreated water.

Xylene used for control of aquatic weeds in irrigation canals dissipated, as treated water moved through the canal. The initial concentrations of 548 to 760 p/m declined to below an average of 100 p/m after the water had traveled 10 miles and a booster application of 277 to 412 p/m extended the effective concentration an additional 3 to 4 miles downstream. In furrow irrigation, xylene concentrations decreased once the treated water reached the fields, and they declined to undetectable amounts by the time the treated water left the field. The negligible level of xylene (< 0.2 p/m) that entered return flows of irrigation water was insufficient to kill fish, produce off-flavor, or degrade water quality.

APPLICATIONS

Rainbow trout may be killed by exposure to xylene concentrations over a 2-hour period exceeding 7.1 to 16.1 p/m and concentrations of about 3 p/m cause them to lose equilibrium. A concentration of 0.1 p/m has been experimentally shown to cause avoidance of young rainbow trout [19]. In the few instances where fisheries in canals require protection, xylene concentrations in the water should not exceed 1 p/m for more than 2 hours. Longer exposure may result in off-flavor in the fish. Since applications at low rates are not practical for effective aquatic weed control, treatments with emulsified xylene are not compatible with the maintenance of a fishery in canal waters. Direct return flows of irrigation water to rivers, streams, and other aquatic habitats containing desirable fish should also not contain more than 1 p/m of xylene immediately downstream from the discharge. EPA (Environmental Protection Agency) pesticide labeling of xylene as an herbicide permits 10 p/m residues in water. However, findings in the present study indicate that concentrations as high as 10 p/m should be reduced or diluted to below 0.2 p/m before the residues reach fish populations. The negligible quantities of xylene (< 0.2 p/m) that may remain in treated irrigation water after passing through irrigation fields and into return flows should not adversely affect fisheries.

MATERIALS AND METHODS

Xylene Treatments to Rainbow Trout

Test Facility. — The study was conducted at the Bureau of Reclamation Aquatic Weed Research Station (fig. 1) located east of Dam No. 1 on Carter Lake, about 7 miles west of Berthoud and 45 miles north of Denver, Colo. This facility was described in a previous laboratory report [8]. The two flumes, or artificial streams, are separated into five sections, each 150 feet long. The first section has a concrete bottom and is used for holding stocks of fish used for research, while the other sections have concrete sides. Each section provides a stream type habitat for fish and endemic invertebrates.

Water for the test facility is seepage from Dam No. 1 on Carter Lake. It is occasionally supplemented with water from the St. Vrain Supply Canal, which transports water from Carter Lake. Water flows were maintained at 0.5 to 1.0 ft^3/s throughout the study. Water quality determinations [9] indicate that the seasonal value for pH ranged from 7.9 to 8.7; ranges of chemical characteristics (p/m) were TDS (total dissolved solids), 111-144 p/m; CO_3, 0-8 p/m; HCO_3, 67-94 p/m; and SO_4, 4.1 - 7.8 p/m. The dissolved oxygen values of the water were continuously at or just below saturation. Water temperatures varied between 48° and 52°F.

Fish. — Test fish were rainbow trout, *Salmo gairdneri*, supplied from the Hotchkiss, Colo., National Fish Hatchery. At stocking, the fish were 238 ± S.E. (standard error) 53 mm in forked length, weighed 165 ± 8.6 gm and were in good condition (average condition factor = 1.09) when delivered to the facility on August 3, 1972. The required number of fish were placed in the testing sections of the flumes about 2 weeks before xylene exposures started.

Xylene and emulsifier. — Xylene used in this study was an industrial grade material similar to that purchased for aquatic weed control programs by the Bureau of Reclamation. The xylene used is equivalent, or better than, grade B covered in Federal Specifications TT-X-916 [10], and are the same specifications as the xylene used in organic coatings. About 1.1 to 1.5 percent by volume of an emulsifying agent was dissolved in the xylene to provide good dispersion when added to water. These emulsifying agents had been proven suitable for this purpose through laboratory tests [18] and field use.

Exposure. — The trout were exposed to average xylene concentrations of 0.36, 0.74, and 1.3 p/m for 56 days in one flume; and to 0.64, 3.6, 7.1, 16.1, and 25.6 p/m for 2 hours in the other flume. These concentrations were confirmed by GLC (gas-liquid chromatography) analyses of water samples collected during the treatments. Because water flowed from the first section through each succeeding section of flume, xylene solutions were added at each downstream section to maintain the desired concentrations. The first section of each flume held the untreated control fish.

Before the tests were started, the flourescein dye that was added to each flume showed that the distance required for complete mixing was within the first 25 feet in each section. Therefore, screens were inserted at this

Figure 1.—Aquatic Weed Test Station, Carter Lake, Colo. The two artificial streams (flumes) are shown that were used during the 1972 xylene study. The flume on the left was used for the 56-day exposure, the flume on the right was used for the 2-hour exposure, while the area between the flumes is for waste water. The arrow shows the water bath containing the Mariotte bottle for constant metering of xylene. Each section is separated by a drop structure, as indicated by the water flowing over the head-boards on each flume. Photo P801-D-76762

point in each section to restrict movement of the trout and prevent their exposure to unmixed xylene.

A water bath using flume water was constructed for each Mariotte stock bottle to maintain consistent hydrostatic pressure and temperature of the stock solution (fig. 2). Long term applications were made by dripping the xylene and emulsifier solution from a Mariotte stock bottle through Teflon tubing fitted with a 22-gauge hypodermic needle. Desired concentrations were maintained by changing the solution quantities of flow by adjusting the relative elevation difference between the bottom of the air tube needle (fig. 3).

Emulsified xylene in water used for short term 2-hour exposures was applied from a 5-gallon pressurized can from an overhead constant head tank (fig. 4).

Analyses of xylene residues. — The fish were analyzed for xylene residues in the fillets by using the methods of Benville [11]. Fish fillets, (20 g), were homogenized with 40 g of anhydrous sodium sulfate and 50 ml of 95 percent ethyl alcohol for 1 minute. The mixture was rinsed into a 1-litre round bottomed flask with 30 ml of 95 percent ethyl alcohol. The mixture was distilled, and 60 ml of distillate were collected and added to a 125-ml separatory funnel containing 70 ml of distilled water, 5 ml of carbon tetrachloride, and 0.5 ml of concentrated hydrochloric acid. The mixture was then shaken for 2 minutes; the phases were allowed to separate, and the carbon tetrachloride layer was transferred to a 60-ml separatory funnel. Distilled water (1 ml) was added and the mixture shaken for 1 minute. The carbon tetrachloride was transferred to a vial for quantification by GLC (gas liquid chromatogy). The analysis of tissue samples spiked with 14C-labeled xylene yielded a 92-percent extraction efficiency.

The analyses of fish were conducted with a Beckman Model GC-72-5 gas chromatograph equipped with a flame ionization detector. The column was stainless steel 12 ft by 1/8 in, packed with acid-washed, 60 to 80 mesh Chromosorb W, deactivated with dimethyldichlorosilane, and coated with a combination of 5-

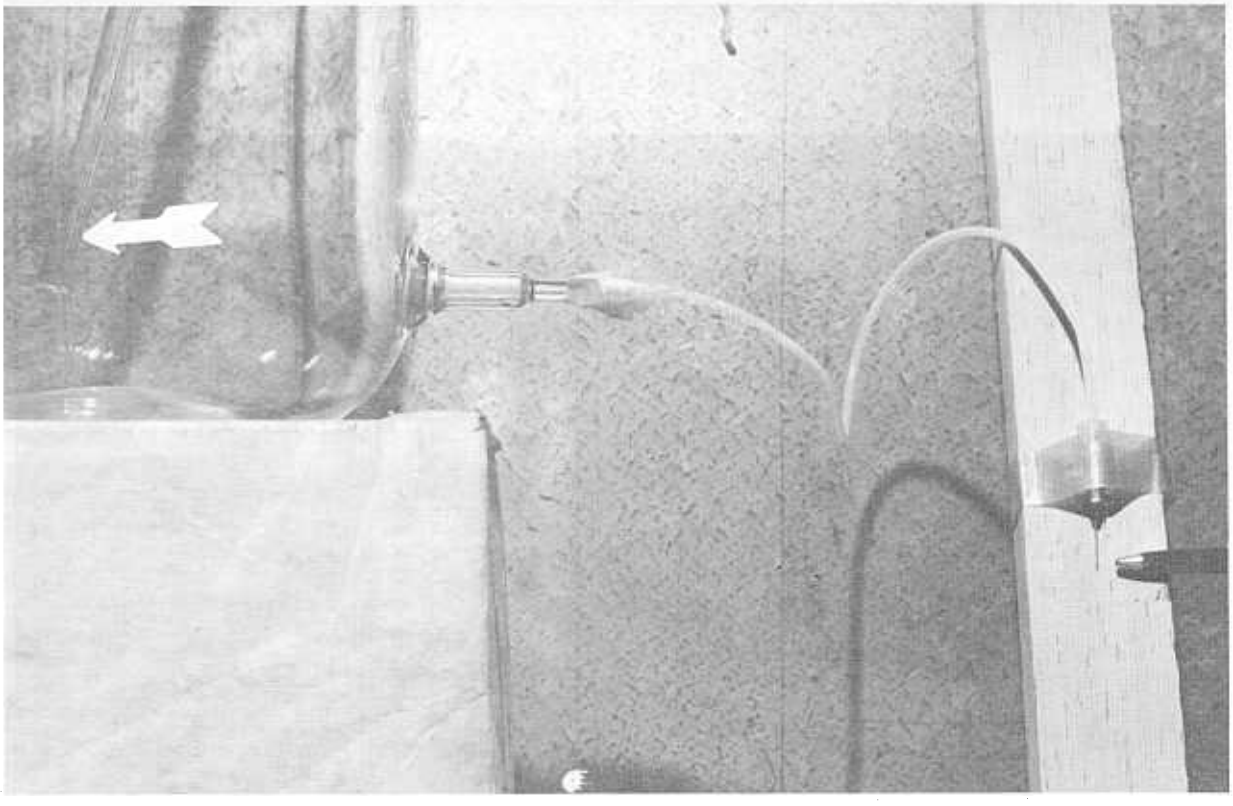

Figure 2.–Water bath and Mariotte bottle (long term). This was used to deliver predetermined volumes of emulsified xylene for 56 days. The vertical distance between the bottom of the air tube inside the bottle (shown by arrow) and the needle tip regulated the flow of xylene. Photo P801-D-77455

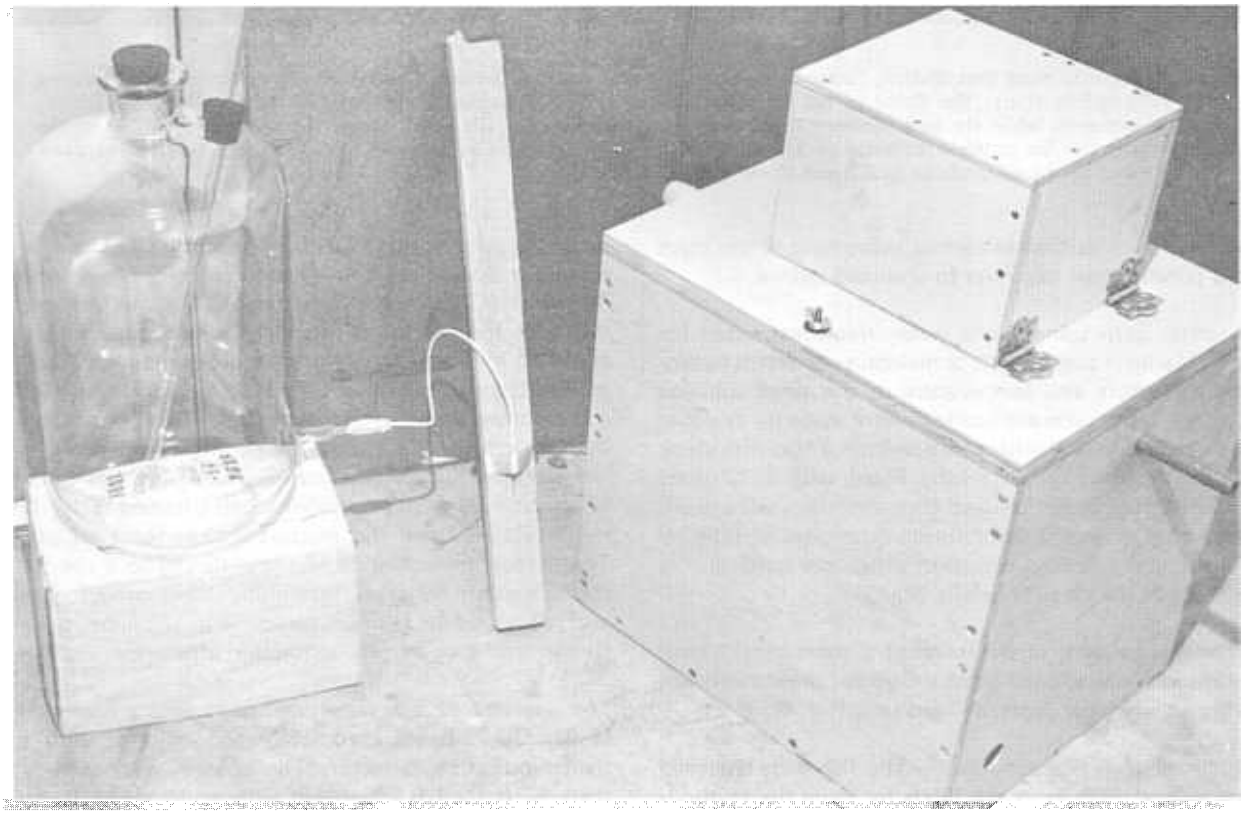

Figure 3.–The Mariotte bottle used to deliver predetermined volumes of emulsified xylene (long term). The needle attached to the Mariotte bottle with Teflon tubing protruding through the small hole near the bottom of the box allowed calibration after constant temperature was attained. Photo P801-D-77456

a. The xylene and emulsifier in the overhead constant head bottle was dripped into the water to provide the desired concentrations. Photo P801-D-77457

b. The emulsion of xylene in the 5-gallon container was pressurized to maintain the required dosage rate. Photo P801-D-77458

Figure 4.–Methods used to apply xylene for the 2-hour exposure.

percent Bentone 34, and 5-percent diisodecyl phthalate [12]. The column, injector, and detector temperatures were adjusted to 80, 155, and 140°C, respectively. Helium, hydrogen, and air flows were 100, 45, and 300 cm^3/min, respectively.

Water samples were taken at the 1st, 3rd, 7th, 14th, and 56th day during the continuous exposure of trout to xylene and at 0.5, 1.0, and 1.5 hours during, and 1 and 24 hours after the 2-hour exposures. The samples were collected, extracted, and analyzed by methods described by Frank [13].

Toxicity tests. – The acute toxicity of xylene, xylene plus Emcol AD-410 emulsifier, and Emcol AD-410 alone were determined at the U.S. Fish and Wildlife Service, Fish-Pesticide Research Laboratory, Columbia, Mo. The toxicity tests were conducted with rainbow trout weighing 0.9 g. The tests were conducted according to the methods of the Committee on Methods for Toxicity Tests with Aquatic Organisms [14]. The LC_{50}'s and 95 percent confidence intervals were calculated according to Litchfield and Wilcoxon [15]. Briefly, LC_{50} is the median lethal concentration, the concentration of toxicant in the environment which kills 50 percent of the organisms exposed to it.

Off-flavor analysis. – Fillets of eight fish from each xylene treatment were collected at 1, 3, 7, 14, and 56 days of exposure and at the end of the 2-hour exposure. After each fish was weighed and measured, the two fillets were removed, wrapped in aluminum foil, and frozen. One was used for taste evaluation and the other for residue analyses. Off-flavor evaluations of the fish were made by personnel of the Sensory Evaluation Section of the department of Food Science and Technology, Oregon State University. The procedures followed by this evaluation team were described by Shumway [16]. Briefly, the procedure included cooking the cleaned fish fillet in aluminum foil without seasoning at about 210°C until done (30 to 40 minutes). The fillets were then served to a panel of tasters. Off-flavor and overall desirability were evaluated on a scale ranging from 0 (very desirable) to 6 (very undesirable). Because of the variation in taste from one population of fish to another, all of the fish, including the controls, were evaluated with reference to a fish with known taste characteristics. The reference fish are maintained by the Oregon State University's Averill Fisheries Laboratory. Data were statistically treated for experimental differences by two-way analysis of variance. The relationship between the three xylene concentrations in water and the resultant residues in fillets were tested separately by linear regression analyses of variance.

The identification of values for individual fish fillets was lost during the analyses for off-flavor and residues; therefore, the relationship between off-flavor with individual residue values was correlated using Pearsons Product Moment Correlation Coefficient [17].

Xylene Treatments in Irrigation Systems

Test Canals. – Operational irrigation canals in several western states were used to study the residue dynamics and persistence of emulsified xylene in irrigation systems, (table 1). The Rock Branch and Cherry Creek Laterals in Wyoming, Farmers Ditch in Colorado, and the Kennewick Main Canal and W-26 E Lateral in Washington were selected for study of xylene concentrations in canals. The W-26C, W-35.9D, W-61F, and PE412 laterals on the Columbia Basin project in Washington were used to determine residues in treated water as the water passed from laterals, through furrow-irrigated fields, and into return flows, (table 2). The xylene used was the same as that previously described.

Treatments. – Applications of emulsified xylene were made by canal operators or research personnel. All treatments were similar in that a certain volume of xylene, depending on water discharge, plus 1 to 2-percent emulsifier were injected into the water in less than 1 hour. The maximum application for aquatic weed control was 10 gallons of xylene per ft^3/s of water flow, the application to be made within a 30 minute period. This rate gives a calculated maximum recommended application concentration of 740 p/m xylene. Characteristics of irrigation canals and laterals, and the types and amounts of xylene applied to study xylene residues in irrigation water and return flows are summarized in tables 1 and 2. All of the canals were of earth construction in the areas studied. A typical xylene application for control of aquatic weeds in an irrigation canal is illustrated in figure 5.

Sampling of treated water. – Rhodamine B type dye was applied at a rate of about 50 p/m to irrigation water at both the start and finish of each xylene application to mark the segment of treated water. Also, additional dye was added as needed at downstream points to trace the treated water throughout the canals and fields. Triplicate water samples were collected for each of the sampling times at each station. A 15-ml volume of CCl_4 (carbon tetrachloride) was added to the quart-size glass sample bottles before the sample was collected so that the xylene could be partitioned into the CCl_4 for preservation until extraction and analysis were performed in the laboratory as described in analyses of xylene residues.

Concentrations of xylene in artificial streams were verified by chemical analyses. Post-treatment samples taken 1 hour after 2-hour exposures showed that the residual xylene was below the detection limit of 0.2 p/m.

Table 1.—*Characteristics of, and treatment data for irrigation systems used to study residues of xylene in irrigation water*

Item	Irrigation systems and date of treatment					
	Farmers Ditch 10-12-67	Farmers Ditch 10-1-69	Cherry Creek Lateral 9-29-67	Rock Ranch Canal 7-15-69	Kennewick Main Canal 7-16-68	W-16 E Lateral 8-6-68
Normal capacity (ft^3/s)	25	25	–	–	–	90
Rate of flow (ft^3/s)	11	15	13	58	82	[1]89(70)
Average water velocity (ft/s)	–	1.3	–	1.4	–	–
Length of canal (mi)	–	9	–	10	17.5	16
Water temperature (°C)	–	12	–	20	–	–
Calculated treatment rate						
No. 1 (p/m)	577	600	555	548	555	760
Booster (p/m)	–	–	–	–	277	412
Volume of xylene applied						
No. 1 (gal)	100	150	120	430	410	890
Booster (gal)	–	–	–	–	205	350
Duration of application						
No. 1 (min)	35	37	37	30	20	29
Booster (min)	–	–	–	–	20	27
Emulsifier quantity (% vol./vol.)	2	2	2	2	1	1
Emulsifying agent[2]	E	E	E	E	Ch	Ch
Xylene product[3]					Cy	Cy

[1] Flow at point of booster application.
[2] E = Emcol AD-410; CH = Chapcol 14Z
[3] Cy = Cyclosol 31

Table 2.—*Characteristics of, and treatment data for laterals used to study xylene residues in return flows*

	Lateral			
	W-26C	W-35.9D	W-61F	PE 41.2
Normal capacity (ft^3/s)	89	85	114	43
Rate of flow (ft^3/s)	17.2	16.1	18.3	22.8
Computed concentration (p/m)	740	740	444	740
Volume of xylene applied (gal)[1]	500	230	370	350
Duration of application (min)	30	30	25	30
Emulsifier quantity (% vol./vol.)	1	1	0.25	1
Emulsifying agent[2]	R	R	R	Em
Date of treatment	6-11-73	6-12-73	6-18-73	7-5-73
Crop irrigated	Radish (seed)	Sugar beets	Alfalfa	Corn
Length of irrigation rills (feet)	1,320	800	750	800

[1] Xylene product: Socal 3501
[2] R = Retzloff A-2029
Em = Emcol AD-410

Figure 5.–Application of emulsified xylene for control of aquatic vegetation in an irrigation canal. This is a location in the Columbia Basin Project. The milky appearance of the irrigation water is caused by the xylene emulsion formed by mixing the xylene and emulsfier with irrigation water in the pump on the truck and introducing it through the hose into the canal. Photo P801-D-77459

RESULTS AND DISCUSSIONS

Effects of Xylene on Rainbow Trout

Acute Toxicity to fish. – The calculated 24 and 96-hour LC_{50} toxicities for xylene to rainbow trout were both 13.5 p/m with confidence intervals ranging from 9.5 to 19.2 p/m (table 3). There appears to be little, if any, difference in toxicity between technical xylene and emulsified xylene. Also, toxicity does not increase at exposures beyond 24 hours. The data indicated that concentrations between 7 and 10 p/m would probably cause no mortality but that concentrations about 20 p/m might cause 100 percent mortality.

The toxicity of xylene to larger rainbow trout (200 g and larger) in artificial streams closely approximated the toxicity determined for the small trout used in the laboratory tests. The apparent level where there is no effect on the fish for a 2-hour exposure to xylene was from 7.1 to 16.1 p/m (table 4), which is close to the predicted 7 to 10 p/m. The lethal effect of xylene is probably quick, because the results of laboratory and stream studies are similar regardless of the length of exposure. The laboratory tests show that concentrations in excess of 20 p/m would cause total mortality whereas the stream tests showed that 16.1 p/m was completely lethal. Concentrations of xylene exceeding 7 to 10 p/m may cause mortalities of rainbow trout in canals and should not be permitted to enter natural streams or reservoirs.

Behavior of fish. – Though xylene was not lethal at concentrations of 7 p/m and below, the fish appeared to be distressed at concentrations as low as 3.6 p/m. More than 90 percent of the rainbow trout exposed to 7.1 p/m xylene for 2 hours lost their equilibrium within the first 1.5 hours. The response resembled that induced by an anesthetic. Also for about a half hour after exposure they did not swim away when one approached the stream as would have been normal behavior. Those exposed to 3.6 p/m behaved similarly, but the response was less severe. In a swiftly flowing canal or natural stream, trout exposed to 7.1, or even 3.6 p/m probably

Table 3.—*Acute toxicity of xylene, emulsified xylene (xylene plus Emcol AD-410) and Emcol AD-410, to rainbow trout*

Chemical	Average weight of fish, (g)	Water conditions				LC_{50} and 95% confidence limits	
		Temperature, (C°)	Ph	Alkalinity, (p/m)	Hardness, (p/m)	24 hour, (p/m)	96 hour, (p/m)
Xylene (technical)	0.9	12	7.2 to 7.6	30 to 35	40 to 48	13.5 (9.5 to 19.2)	13.5 (9.5 to 19.2)
Xylene +2% AD-410	0.9	12	7.2 to 7.6	30 to 35	40 to 48	17.3 (11.9 to 25.1)	17.3 (11.9 to 25.1)
AD-410	0.9	12	7.2 to 7.6	30 to 35	40 to 48	9.6 (7.1 to 13)	9.0 (6.7 to 12.2)

Table 4.—*Toxicity of xylene to rainbow trout in artificial streams*

Mean (± SD) (n = 8) Concentration, (analyzed) (p/m)	Exposure time	Mortality, (%)
25.6	2 hrs.	100 in 24 hrs.
16.1	2 hrs.	100 in 24 hrs.
7.1 (1.2)	2 hrs.	0
3.6 (0.19)	2 hrs.	0
0.64 (0.1)	2 hrs.	0
1.3 (0.13)	56 days	0
0.74 (0.19)	56 days	0
0.36 (0.09)	56 days	0

could not have maintained their positions. Factors such as predation or swift current could increase the mortality rate of the affected fish at these exposure levels. If alternate habitats were available rainbow trout might avoid even low concentrations of xylene. Folmar [19] reported that rainbow trout actively avoid xylene concentrations as low as 0.1 p/m.

Rainbow trout exposed to 0.36, 0.74, or 1.3 p/m xylene for 56 days did not appear to be adversely affected, i.e., they were not killed and behavior of all individuals was similar to that of the controls.

Off-flavor of fish. — Evaluation of flavor in fish exposed to xylene for 2 hours or 56 days indicated that the off-flavor index was dependent upon concentration and duration of exposure (figs. 6 and 7).

Fish sampled 24 hours after the 2-hour exposure to 7.1 p/m of xylene had a significant ($P < .05$) off-flavor (fig. 6). However, all other trout from the 2-hour exposure were comparable with controls through the seventh day after exposure.

Rainbow trout exposed to a concentration as low as 0.36 p/m had a significant ($P < .05$) off-flavor throughout the 56-day exposure. Off-flavor was maximum in fish after 3 days of exposure (fig. 7). During continuous exposures of trout to xylene, the higher the concentrations, the greater the off-flavor index. The index increased rapidly after initial exposure, reached a plateau, and then declined. Persumably, off-flavor is associated with residues of xylene in the muscle.

Short-term non-lethal exposures of rainbow trout to xylene would probably impair the flavor of the fish flesh for several days, unless the fish could avoid the xylene by moving to suitable alternate habitats.

Xylene residues in fish. — GLC analyses of fillets from xylene-treated rainbow trout indicated that uptake of xylene was rapid. Detectable residues were measured 1 day after a 2-hour exposure to 0.64 p/m but had been eliminated within 7 days in all trout exposed for 2 hours (table 5). Analysis of variance of residue data from rainbow trout continuously exposed to low concentrations of xylene showed that there was no difference in residues between 2 and 56 days or within any of the exposure concentrations (fig. 8). Residues, like the off-flavor index, increased rapidly, and either decreased (after the 2-hour exposure) or reached a plateau (during the continuous exposure).

Off-flavor vs. xylene residues in fillets. — The mean off-flavor index and xylene residues in fillets were correlated significantly ($P < .01$) (table 6). Although we

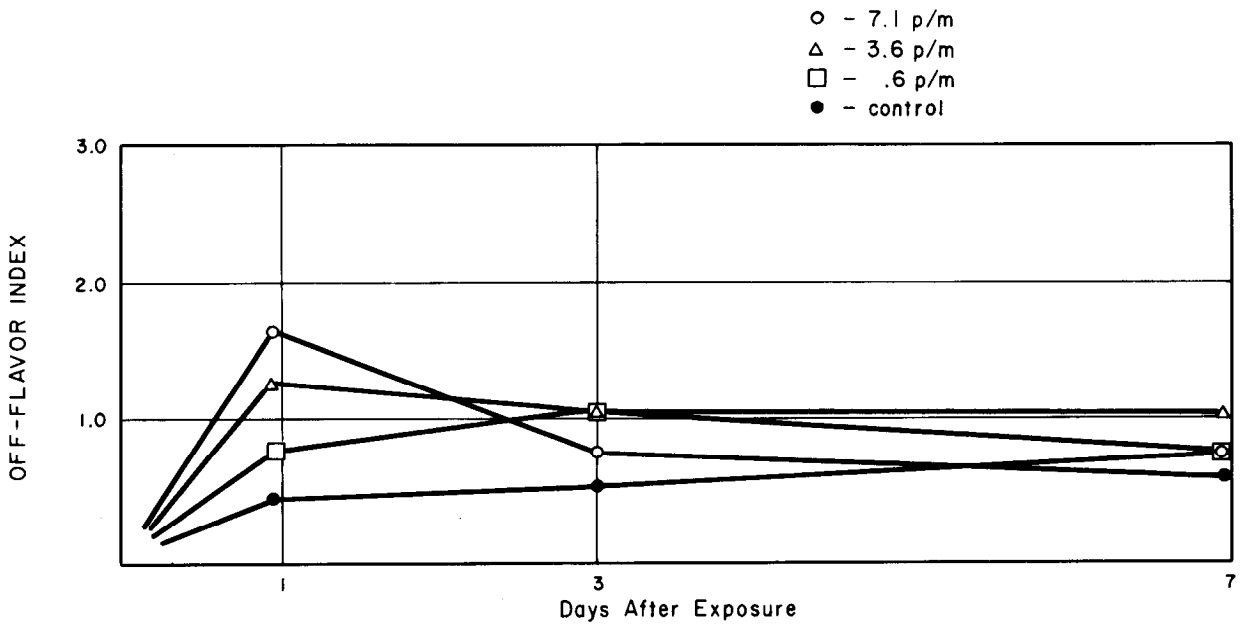

Figure 6.–Off-flavor index in rainbow trout caused by exposure to sublethal concentrations of xylene for 2 hours. The fish were taste tested 1, 3, and 7 days thereafter.

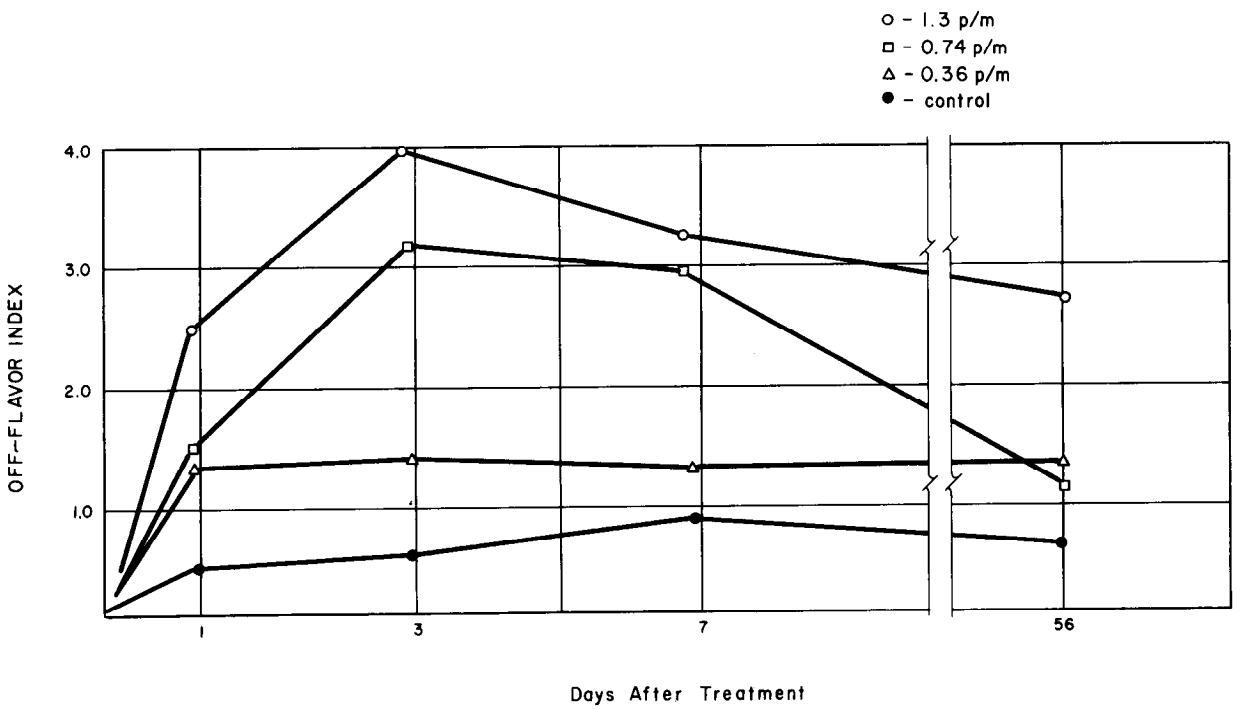

Figure 7.–Off-flavor index in rainbow trout caused by exposure to sublethal concentrations of xylene for 56 days.

Table 5.—*Xylene residues in fillets of rainbow trout exposed to xylene*

	Fillet residue (p/m ± S.D.) in rainbow trout exposed for —					
	2 hours			56 days		
	0.64	3.6	7.1	0.36	0.74	1.3
Sample day[1]						
1	0.68 (0.17)	3.7 (0.92)	4.3 (0.54)	3.3 (1.0)	7.9 (2.6)	18.4 (6.1)
3	0.26 (0.04)	0.78 (0.23)	1.1 (0.23)	—	—	—
7	[2] N.D.	N.D.	N.D.	4.1 (2.1)	10.9 (3.9)	11.1 (5.5)
56	N.D.	N.D.	N.D.	5.0 (2.2)	10.9 (5.3)	16.0 (5.0)

[1] Xylene was not detectable in the control fish on any sample date (date not shown in the table).
[2] N.D. — Fillets analyzed contained less than 0.20 p/m.

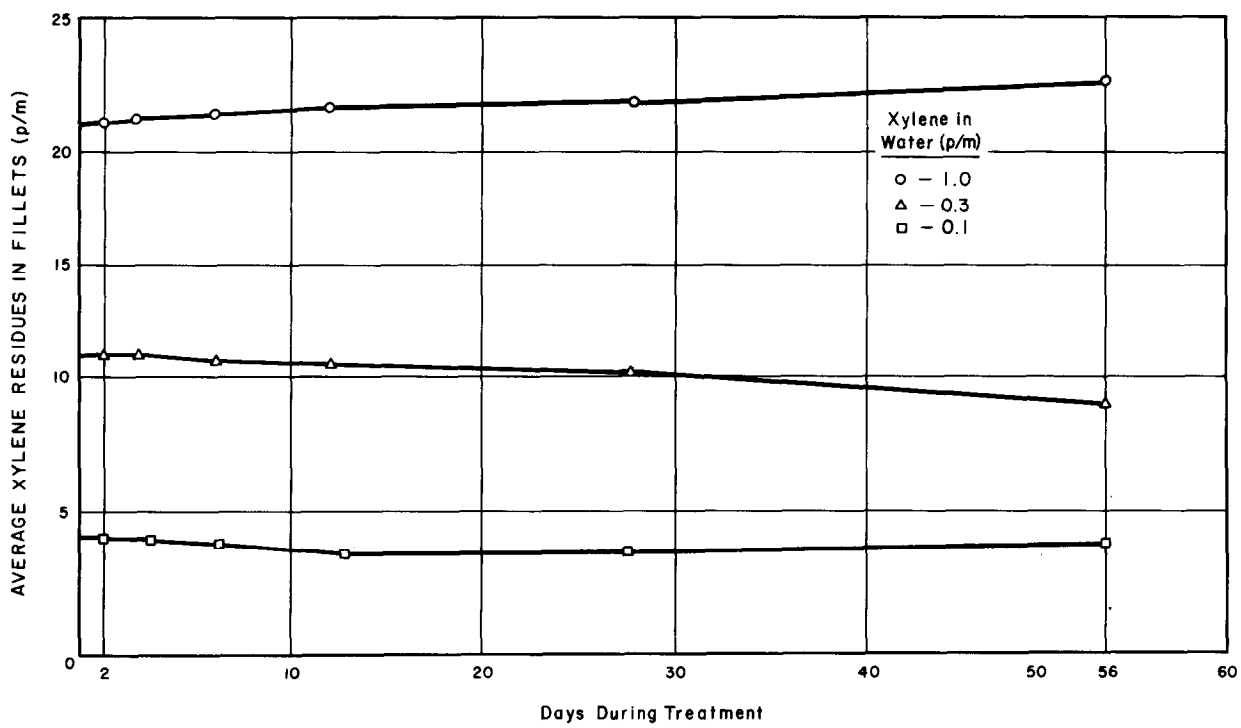

Figure 8.—Average residues of xylene in fillets of rainbow trout after exposure to various concentrations of xylene in water over a 56-day treatment.

Table 6.—*Off-flavor index and residues in rainbow trout exposed to sublethal concentrations of xylene for 56 days*

Mean (± SD)[1]	Exposure Period (Days)					
	1-day		7-day		56-day	
Concentration in water, (p/m)	Off-flavor index[2]	Residue,[3] (p/m)	Off-flavor index	Residue,[3] (p/m)	Off-flavor index	Residue,[3] (p/m)
		4.9		7.5		2.6
		3.6		2.8		3.6
		3.3		5.5		7.7
0.36 (0.09)	1.35	3.4	1.26	2.0	1.20	4.4
		2.8		2.6		5.2
		2.0		4.2		5.0
		4.4		4.1		8.7
		2.2		[4]NA		3.0
		7.4		10.1		7.9
		11.0		13.6		14.4
		10.0		7.4		19.2
0.74 (0.19)	1.56	6.7	3.06	16.0	1.0	6.0
		4.3		8.8		6.0
		9.4		14.5		11.6
		9.6		5.6		10.0
		4.4		NA		NA
		14.4		6.4		24.0
		27.6		15.6		17.2
		17.6		13.6		9.6
1.3 (0.13)	2.41	10.0	3.26	7.6	2.53	15.8
		20.4		6.4		13.9
		14.8		20.4		21.4
		24.0		7.8		15.0
		NA		NA		10.4

[1] n = 8.
[2] Index based on pooled sample from eight fillets.
[3] Individual fillets.
[4] NA = sample not analyzed.

were unable to develop a "predictive index" based on a regression line, we speculate that an off-flavor is evident when the determined residue is about 2.0 p/m or greater.

Xylene Residues in Irrigation Systems

Residues in canals. — The dissipation rate curves for maximum xylene concentrations measured in water of six treated canals are presented in figure 9.

The concentration of xylene in Farmers' Ditch in 1967 varied widely near the site of introduction of the chemical. However, much of the variation in concentration had disappeared 1 mile downstream, apparently because mixing had become more thorough. Water residues dissipated in this treatment, with the average concentration falling from about 577 p/m to 49 p/m at the 4.4-mile point. The 1969 application to Farmers' Ditch was added at a uniform rate and at a slightly higher concentration to a greater water flow than in 1967.

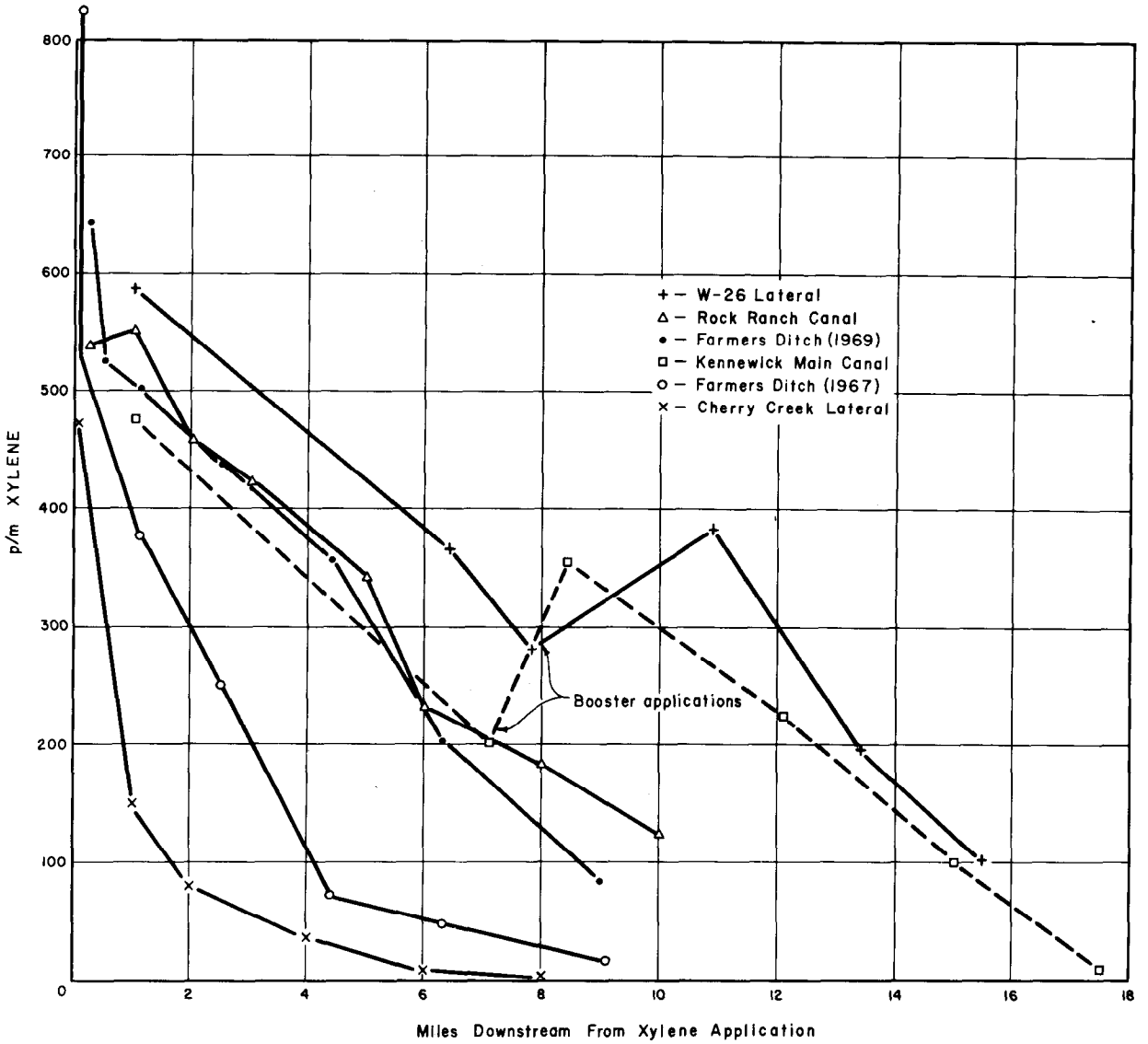

Figure 9.–Dissipation of xylene in six irrigation systems. (Xylene concentrations in water samples collected at downstream sampling stations.)

Xylene residues in the 1969 treatment showed a steady decline as the water moved downstream, from 600 p/m near point of application to an average level of 56 p/m at the 9-mile station. We consider the dissipation of residues in water after the 1969 treatment to be typical of that expected for a canal of this type.

Water concentrations of xylene in the Cherry Creek Lateral dissipated at an unusually rapid rate, from 555 p/m to 10 p/m at the 1-mile point. Factors such as low flow and xylene evaporation in a pool below the canal check contributed to the rapid dissipation or dilution.

Rock Ranch Canal was treated when rate of flow was 58 ft^3/s. The xylene concentration declined gradually as the block of treated water moved downstream from 548 p/m at the point of application to an average of 68 p/m at the 10-mile point.

The Kennewick Main Canal and the W-26 E Lateral were treated during the first of the irrigation season when the rate of flows were 82 and 89 ft^3/s, respectively. Concentrations in each canal were reinforced because of the great length of the waterways in which weed control was required. Although additional xylene

maintained higher residues over a longer distance, the overall trend of residue dissipation was similar to that of canals receiving a single treatment. Residues in these two canals were about 100 p/m near the 15-mile point below the point of initial application.

The xylene concentrations measured in these six canal treatments illustrate that the xylene levels dissipated within the first few miles below the application site. Generally, the average xylene concentration declined to 200-100 p/m, or below after traveling downstream for 5 to 10 miles, respectively. A booster application extended these distances by 3 or 4 miles.

Residues in return flows. – The pattern in which xylene residues dissipated in irrigation water as the treated water moved from laterals, through crop fields and into return flows is illustrated in figure 10.

The concentrations found in these four treatments were very similar. Xylene concentrations dissipated rapidly once the treated water reached cropland, and by the time the treated water had traveled to the end of the rills, the concentration was below the detectable level of 0.2 p/m. Consequently, only negligible quantities were found in return flows. These concentrations should not cause mortality or other adverse effects on fisheries.

CONCLUSIONS

During 2-hour exposures, emulsified xylene appeared to be non-toxic to rainbow trout at concentrations below 7 p/m but concentrations as low as 3.6 p/m may inhibit normal behavior. Treated water returning to fishery habitats should not contain xylene concentrations greater than 1 p/m for a 2-hour exposure.

Detectable off-flavor was produced in rainbow trout after they were exposed to 7.1 p/m of xylene for 2 hours or to 0.36 p/m for up to 56 days. The degree of off-flavor from xylene was directly dependent on concentration and exposure time. The off-flavor dissipated within 1 to 3 days after the fish were exposed to untreated water. Residues of xylene detected in fillets of rainbow trout were directly related to the off-flavor index measured in duplicate fish fillet samples.

Xylene dissipated from irrigation water as the treated water moved down the canal and the average concentration dropped to well below 100 p/m by the time the water had traveled 10 miles. After the xylene-treated water moved through irrigated fields and into return flows, the xylene concentration had declined to a non-detectable level (less than 0.2 p/m); thus return flows entering fishery habitats would not be expected to adversely affect fish.

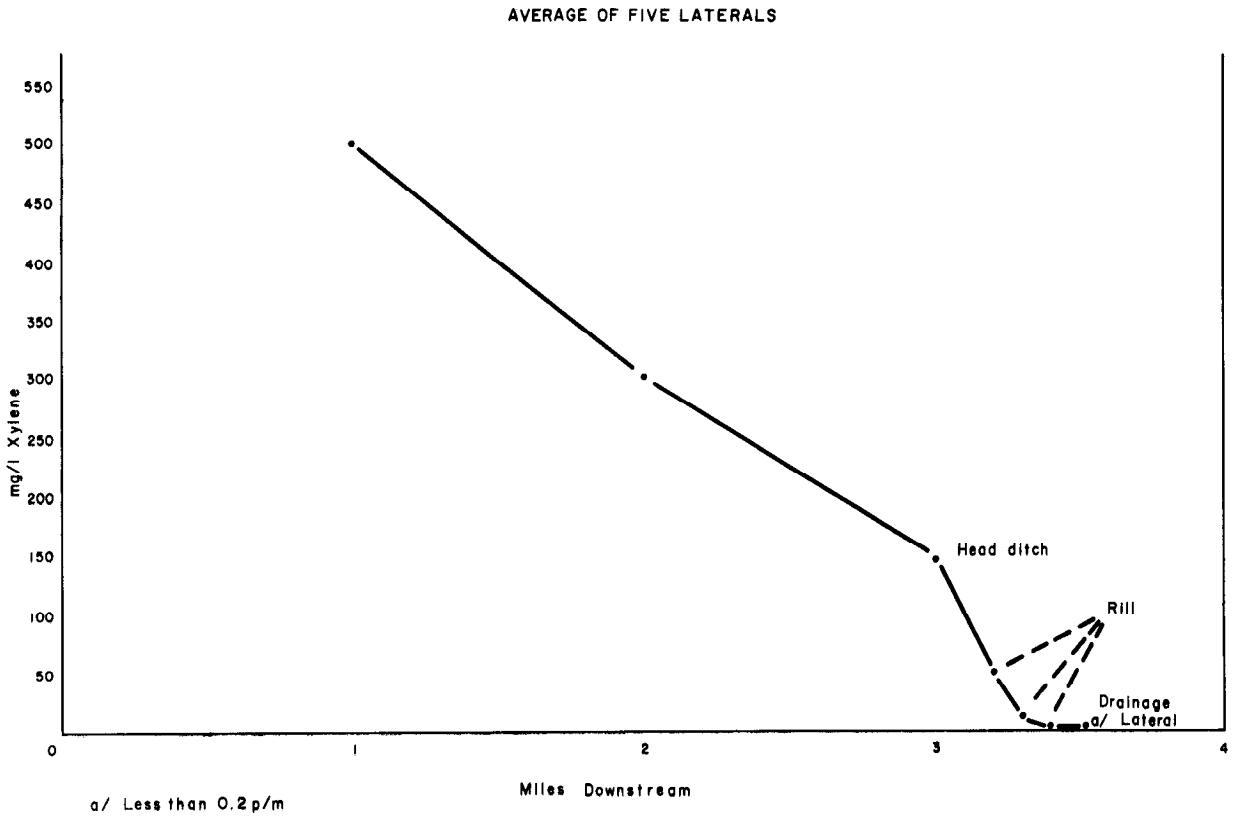

Figure 10.–Dissipation of xylene from laterals, through crop fields, and into return flows.

BIBLIOGRAPHY

[1] Shaw, J. M., T. R. Bartley, and R. S. Rosenfels, "Method of Killing Submerged Water Weeds" Patent Office, Letters Patent No. 2,600,436, June 17, 1952.

[2] Shaw, J. M. and F. L. Timmons, "Controlling Submersed Water Weeds on Irrigation Systems with Aromatic Solvents" Joint report of Bureau of Reclamation and Bureau of Plant Industry, Soils and Agricultural Engineering. Chemistry Laboratory Report No. CH-97, 1949.

[3] Comes, R. D., R. R. Yeo, V. F. Bruns, J. M. Hodgson, and others, "Chemical Control of Submersed Waterweeds in Western Irrigation and Drainage Canals," Joint report of Department of Agriculture. Agricultural Research Service, and Bureau of Reclamation, Agricultural Research Service Report No. ARS 35-57, 1963.

[4] Bartley, T. R. "Physical and Chemical Properties Indicative of Good Hydrocarbon Solvents for Aquatic Weed Control in Irrigation Systems" Proceedings, Western Weed Control Conference, 16:34-39, 1958.

[5] Bruns, V. F., R. R. Yeo, H. F. Arle, "Tolerance of Certain Crops to Several Aquatic Herbicides in Irrigation Water" Department of Agriculture Technical Bulletin No. 1299, 1964.

[6] Bartley, T. R., J. G. Armstrong, and P. A. Frank, "Some Effects of Xylene and Acrolein on Rainbow Trout" Weed Science Society of America, WSSA Abstracts No. 90, Abstracts of the 1974 meeting in Las Vegas, Nevada, 1974.

[7] Bruns, V. F. and A. D. Kelley, "Effect of Sprinkler Irrigation with Xylene-Treated Water on Six Crops" College of Agriculture Research Center, Washington State University, Pullman, Wash., Bulletin 796, 1974.

[8] Bartley, T. R., "Aquatic Weed Test Station" Water Conservation Report No. WC-24, Bureau of Reclamation, December 1, 1965.

[9] Otto, N. E., P. M. Turner, and V. S. Miyahara, "Progress Report on Aquatic Weed and Algae Control Studies" Bureau of Reclamation Report REC-ERC-72-35, October, 1972.

[10] "Federal Specification for Xylene, for Use in Organic Coatings" Federal Specification TT-X-916.

[11] Benville, P. E., Jr., and R. C. Tindle, "Dry Ice Homogenization Procedure for Fish Samples in Pesticide Residue Analysis" Agricultural Food Chemistry, vol. 18, pp. 448-449, 1970.

[12] Mortimer, J. V. and P. L. Gent, "Use of Modified Bentone-34 for the Gas Chromatographic Separation of Aromatic Hydrocarbons" Nature vol. 197, no. 4869, pp. 789-799, 1963.

[13] Frank, P. A., "Analysis of Emulsified Xylene in Water" Weed Science, vol. 16, no. 4, pp. 489-490, October 1968.

[14] "Methods for Acute Toxicity Tests with Fish, Macroinvertebrates and Amphibians" Committee on Methods for Toxicity Tests with Aquatic Organisms, Environmental Protection Agency, Ecological Research Series, EPA-660/3-75-009, 1975.

[15] Litchfield, J. T., Jr., and F. Wilcoxon, "A Simplified Method of Evaluating Dose Effect Experiments" Journal of Pharmacology and Experimental Therapy, vol. 96, no. 2, pp. 99-113, 1949.

[16] Shumway, D. L. and J. R. Palensky, "Impairment of Flavor of Fish by Water Pollutants" Environmental Protection Agency, Ecological Research Series, EPA-R3-73-010, Project 18050 DDM, 1973.

[17] Sokal, R. R. and F. J. Rohlf, "Biometry" W. H. Freeman, San Francisco, 1969.

[18] Bartley, T. R., "Evaluation of Emulsifiers for Use With Aromatic Solvent Aquatic Weed Killers and Test Method Used for Evaluating Emulsifiers" Bureau of Reclamation, Chemical Engineering Laboratory Report No. W-1, 1961.

[19] Folmar, L. C., "Overt Avoidance Reactions of Rainbow Trout Fry to Nine Herbicides" Bulletin of Environmental Contaminants and Toxicology, 1976.

GPO 840-570

ABSTRACT

Emulsified xylene is used to control aquatic weeds in irrigation systems which may occasionally return irrigation water to aquatic habitats that maintain trout populations. Laboratory studies were conducted to determine effects of xylene on rainbow trout, *Salmo gairdneri*, and to measure dissipation of xylene residues in irrigation water as treated water flowed through canals, irrigated fields, and into return flows.

Rainbow trout exposed to emulsified xylene for 2 hours survived a concentration of 7.1 p/m (parts per million), but suffered 100 percent mortality at 16.1 p/m. An off-flavor was produced in fillets of rainbow trout after exposure to 7.1 p/m of xylene for 2 hours, or to 0.36 p/m for 56 days, and was dependent on concentration and exposure. Residues of xylene in fillets of rainbow trout and off-flavor was directly related. Xylene dissipated downstream in irrigation canals, from treatment concentrations of 548 to 760 p/m to an average concentration of 100 p/m or below after the water traveled 10 miles. Xylene residues dissipated in treated irrigated field waters during furrow irrigation from 150 p/m at the head ditch to less than 0.2 p/m in return flows. The xylene residues entering aquatic habitats in return flows from irrigated fields should not seriously affect fisheries or other segments of the aquatic environment.

ABSTRACT

Emulsified xylene is used to control aquatic weeds in irrigation systems which may occasionally return irrigation water to aquatic habitats that maintain trout populations. Laboratory studies were conducted to determine effects of xylene on rainbow trout, *Salmo gairdneri*, and to measure dissipation of xylene residues in irrigation water as treated water flowed through canals, irrigated fields, and into return flows.

Rainbow trout exposed to emulsified xylene for 2 hours survived a concentration of 7.1 p/m (parts per million), but suffered 100 percent mortality at 16.1 p/m. An off-flavor was produced in fillets of rainbow trout after exposure to 7.1 p/m of xylene for 2 hours, or to 0.36 p/m for 56 days, and was dependent on concentration and exposure. Residues of xylene in fillets of rainbow trout and off-flavor was directly related. Xylene dissipated downstream in irrigation canals, from treatment concentrations of 548 to 760 p/m to an average concentration of 100 p/m or below after the water traveled 10 miles. Xylene residues dissipated in treated irrigated field waters during furrow irrigation from 150 p/m at the head ditch to less than 0.2 p/m in return flows. The xylene residues entering aquatic habitats in return flows from irrigated fields should not seriously affect fisheries or other segments of the aquatic environment.

ABSTRACT

Emulsified xylene is used to control aquatic weeds in irrigation systems which may occasionally return irrigation water to aquatic habitats that maintain trout populations. Laboratory studies were conducted to determine effects of xylene on rainbow trout, *Salmo gairdneri*, and to measure dissipation of xylene residues in irrigation water as treated water flowed through canals, irrigated fields, and into return flows.

Rainbow trout exposed to emulsified xylene for 2 hours survived a concentration of 7.1 p/m (parts per million), but suffered 100 percent mortality at 16.1 p/m. An off-flavor was produced in fillets of rainbow trout after exposure to 7.1 p/m of xylene for 2 hours, or to 0.36 p/m for 56 days, and was dependent on concentration and exposure. Residues of xylene in fillets of rainbow trout and off-flavor was directly related. Xylene dissipated downstream in irrigation canals, from treatment concentrations of 548 to 760 p/m to an average concentration of 100 p/m or below after the water traveled 10 miles. Xylene residues dissipated in treated irrigated field waters during furrow irrigation from 150 p/m at the head ditch to less than 0.2 p/m in return flows. The xylene residues entering aquatic habitats in return flows from irrigated fields should not seriously affect fisheries or other segments of the aquatic environment.

ABSTRACT

Emulsified xylene is used to control aquatic weeds in irrigation systems which may occasionally return irrigation water to aquatic habitats that maintain trout populations. Laboratory studies were conducted to determine effects of xylene on rainbow trout, *Salmo gairdneri*, and to measure dissipation of xylene residues in irrigation water as treated water flowed through canals, irrigated fields, and into return flows.

Rainbow trout exposed to emulsified xylene for 2 hours survived a concentration of 7.1 p/m (parts per million), but suffered 100 percent mortality at 16.1 p/m. An off-flavor was produced in fillets of rainbow trout after exposure to 7.1 p/m of xylene for 2 hours, or to 0.36 p/m for 56 days, and was dependent on concentration and exposure. Residues of xylene in fillets of rainbow trout and off-flavor was directly related. Xylene dissipated downstream in irrigation canals, from treatment concentrations of 548 to 760 p/m to an average concentration of 100 p/m or below after the water traveled 10 miles. Xylene residues dissipated in treated irrigated field waters during furrow irrigation from 150 p/m at the head ditch to less than 0.2 p/m in return flows. The xylene residues entering aquatic habitats in return flows from irrigated fields should not seriously affect fisheries or other segments of the aquatic environment.

REC-ERC-76-11
Walsh, D. F., Armstrong, J. G., Bartley, T. R., Salman, H. A., and Frank, P. A.
RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT, *SALMO GAIRDNERI*
Bur Reclam Rep REC-ERC-76-11, Div Gen Res, Jan 1977, Bureau of Reclamation, Denver, 15 p, 10 fig, 6 tab

DESCRIPTORS—/ *emulsifiers/ *aquatic weeds/ *herbicide/ *aquatic weed control/ *irrigation canals/ *fish/ mortality/ off-flavor/ *residues/ *dissipation rate/ environment/ water quality/ aquatic ecosystem
IDENTIFIERS—/ *xylene

REC-ERC-76-11
Walsh, D. F., Armstrong, J. G., Bartley, T. R., Salman, H. A., and Frank, P. A.
RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT, *SALMO GAIRDNERI*
Bur Reclam Rep REC-ERC-76-11, Div Gen Res, Jan 1977, Bureau of Reclamation, Denver, 15 p, 10 fig, 6 tab

DESCRIPTORS—/ *emulsifiers/ *aquatic weeds/ *herbicide/ *aquatic weed control/ *irrigation canals/ *fish/ mortality/ off-flavor/ *residues/ *dissipation rate/ environment/ water quality/ aquatic ecosystem
IDENTIFIERS—/ *xylene

REC-ERC-76-11
Walsh, D. F., Armstrong, J. G., Bartley, T. R., Salman, H. A., and Frank, P. A.
RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT, *SALMO GAIRDNERI*
Bur Reclam Rep REC-ERC-76-11, Div Gen Res, Jan 1977, Bureau of Reclamation, Denver, 15 p, 10 fig, 6 tab

DESCRIPTORS—/ *emulsifiers/ *aquatic weeds/ *herbicide/ *aquatic weed control/ *irrigation canals/ *fish/ mortality/ off-flavor/ *residues/ *dissipation rate/ environment/ water quality/ aquatic ecosystem
IDENTIFIERS—/ *xylene

REC-ERC-76-11
Walsh, D. F., Armstrong, J. G., Bartley, T. R., Salman, H. A., and Frank, P. A.
RESIDUES OF EMULSIFIED XYLENE IN AQUATIC WEED CONTROL AND THEIR IMPACT ON RAINBOW TROUT, *SALMO GAIRDNERI*
Bur Reclam Rep REC-ERC-76-11, Div Gen Res, Jan 1977, Bureau of Reclamation, Denver, 15 p, 10 fig, 6 tab

DESCRIPTORS—/ *emulsifiers/ *aquatic weeds/ *herbicide/ *aquatic weed control/ *irrigation canals/ *fish/ mortality/ off-flavor/ *residues/ *dissipation rate/ environment/ water quality/ aquatic ecosystem
IDENTIFIERS—/ *xylene