Dissipation of 2,4-D Residues in Large Reservoirs

E. O. GANGSTAD

U.S. Army Corps of Engineers,
Washington, DC 20314

ABSTRACT

The 2,4-dichlorophenoxyacetic acid (2,4-D) residue data for reservoirs in British Columbia, Tennessee Valley Authority, Corps of Engineers and Bureau of Reclamation were subjected to step wise multiple regression analysis. Results of this study showed that season, volume and rate were highly significant. The depth of the reservoir (feet) and time after application (days) were not significant, that is, they were adequately measured by the above variables. The standard application rate of 20 to 40 lbs per acre did not produce 2,4-D residues in large reservoirs above the tolerance level of 100 ppb.

INTRODUCTION

Eurasian watermilfoil (*Myriophyllum spicatum* L.) an old-world, rooted, submersed plant has become a most troublesome aquatic weed. Due to its rapid rates of growth, fragmentation, migration, and establishment, Eurasian watermilfoil is a serious and real threat to our water resources. In some reservoir areas, heavy infestations have (a) depressed real estate values, (b) stopped recreational activities such as boating, fishing, skiing, and swimming, (c) clogged municipal water supply intakes (d) clogged intakes and screens through which raw water passes, (e) hindered small boat navigation, caused commercial fishermen to abandon their lines and nets, and (f) provided extensive new breeding areas for mosquitoes.

The most effective and economical method of controlling Eurasian watermilfoil is treatment with the herbicide 2,4-D. Two 2,4-D products are now registered for Eurasian watermilfoil control in programs conducted by the Tennessee Valley Authority (TVA) in reservoirs in the TVA system (EPA Reg. Nos. 264-2 and 264-109).

It is noted that each of the established tolerances for 2,4-D residues in potable water and raw agricultural commodities, that result from applications to control aquatic weeds, is restricted by specific chemical formulation, weed species, using agency, geographic location, and type of site. Other established tolerances for 2,4-D residues in potable water, fish, shellfish, and crop commodities carry similar restrictions.

This study was undertaken in an attempt to describe representative reservoirs according to characteristics which influence the levels, movement, and persistence of residues of 2,4-D herbicide applied for control of aquatic weeds, especially Eurasian watermilfoil e.g., to predict where 2,4-D application would be unsafe.

DISSIPATION FACTORS

Standard conventional descriptions for lakes, impoundments, and similar water systems are based on factors such as origin (e.g., glacial lakes, tectonic lakes, etc.), size and shape, and temperature stratification. Use of these conventional classification systems would not achieve the desired objectives because the factors they are based on do not relate to dissipation of 2,4-D residues (1, 2, 3, 4, 5, 6).

It is well established that the water temperature influences the rate of breakdown of 2,4-D. Where other factors are equal, 2,4-D residues are more persistent in cooler waters. The mean length of growing season (or length of frost-free period) was chosen as an index for the water temperature factor (1, 8, 10).

The volume of water available for dilution in relation to water volume in treatment areas are judged to be important factors. Initial residue concentrations tend to be higher and to persist longer when 2,4-D treatments are made in small water systems. The percentage of total area and volume that is susceptible to aquatic weed infestation tends to be smaller in large water systems, thereby enhancing the dilution potential of large systems when herbicide treatment is considered (1, 8, 11, 12).

Water depth, correlated to some extent with water volume, is another dimension that influences the extent of areas susceptible to rooted aquatic weeds as well as the potential for dilution. Relatively shallow systems are likely to have a higher percentage area and water volume needing herbicide treatment. Ideally, it would be desirable to use the percentage of total area having depth less than about 15 feet or other appropriate depth, but this information is not available (1, 8, 11, 12).

To summarize the above discussion, three descriptive factors were chosen: (1) volume of the water system, selected as an index of potential dilution effects; (2) mean depth, as crude index of susceptibility to rooted aquatic weed infestation and, therefore, to potential extent of herbicide application; and (3) mean length of growing season, an index to temperature effects on herbicide residue degradation.

Criteria or limits for reservoir temperature classes were established as follows:

T_1—Cool to cold; mean length of growing season is less than or equal to 120 days.

T_2—Moderately cool; growing season is 121 to 180 days.

T_3—Warm; growing season 181 to 240 days.

T_4—Moderately hot; growing season is 241 to 300 days.

T_5—Hot to very hot; growing season is 301 to 365 days.

Criteria or limits for reservoir volume classes were established as follows:

V_1—Very small; maximum storage volume is less than or equal to 1,000 acre-feet.

V_2—Small; maximum volume is 1,001 to 10,000 acre-feet.

V_3—Medium; maximum volume is 100,000 acre-feet.

V_4—Large; maximum volume is 100,001 to 1,000,000 acre-feet.

V_5—Very large; maximum volume is greater than 1,000,000 acre-feet.

Criteria for reservoir depth classes were established as follows:

D_1—Very shallow; mean depth (maximum volume in acre-feet divided by maximum surface area in acres) is less than or equal to 12.0 feet.

D_2—Shallow; mean depth is 12.1 to 24.0 feet.

D_3—Medium depth; mean depth is 24.1 to 48.0 feet.

D_4—Deep; mean depth is 48.1 to 96.0 feet.

METHODS AND MATERIALS

The herbicides were applied with conventional equipment at rates of 20 to 100 lb acid equivalent per acre (20.24 to 112.00 kg/ha). Data from the application of 2,4-D-DMA at British Columbia, Melton Hill and Ft. Cobb and 2,4-D-BEE at Kerr Lake were used. Water sampling and chemical analysis for standard methods as discussed for the Tennessee Valley Authority studies were used (11, 12).

MULTIPLE REGRESSION MATRIX ANALYSIS

The 2,4-D residue data for reservoirs at British Columbia, Tennessee Valley Authority, Corps of Engineers and Bureau of Reclamation as presented in Table 1, were subjected to step wise multiple regression analysis using a BMDPIR program and a log function of volume (8). Results are summarized in Table 2. Season, volume and rate were found to be highly significant. The depth of the reservoir (feet) and time after application (days) were not significant, that is, these effects were adequately measured by season, volume and rate. Thus, the multiple correlation was highest with growing season, i.e., temperature, and the volume and rate, to a much lesser degree.

The multiple regression equation is: $y = 113.9088 - 0.4674$ season (days) $- 4.7577$ volume (10005 acre ft.) $+ 0.0130$ rate (lbs. per acre).

TABLE 1. SUMMARY OF RESIDUE DATA RELATED TO LOCATION, RATE AND TIME AFTER APPLICATION OF 2,4-D TO LARGE RESERVOIRS, FOR CONTROL OF EURASIAN WATERMILFOIL.

Okanagan Lake B.C., Can.[1]			Melton Hill Reservoir (TVA)[2]			Robert E. Kerr Reservoir (CE)[3]			Fort Cobb, OK (BR)[4]		
Rate (lbs/ac)	Time (days)	Residue (ppb)	Rate (lbs/ac)	Time (days)	Residue (ppb)	Rate (lbs/ac)	Time (days)	Residue (ppb)	Rate (lbs/ac)	Time (days)	Residue (ppb)
20	1	29	20	1	1	40	1	1	20	1	1
20	2	45	20	2	1	40	2	1	20	2	20
20	3	1	20	3	1	40	3	3	20	3	1
40	1	32	40	1	1	40	1	1	40	1	23
40	2	75	40	2	1	40	2	3	40	2	11
40	3	35	40	3	1	40	3	3	40	3	1
20	1	13	20	1	1	100	1	1	20	1	1
20	2	11	20	2	1	100	2	1	20	2	58
20	3	107	20	3	1	100	3	3	20	3	27
40	1	17	40	1	29	100	1	1	40	1	2
40	2	28	40	2	9	100	2	1	40	2	1
40	3	51	40	3	15	100	3	3	40	3	1
20	1	12	20	1	1	20	1	1	20	1	12
20	2	29	20	2	1	20	2	1	20	2	38
20	3	1	20	3	1	20	3	1	20	3	1
40	1	6	40	1	16	20	1	1	40	1	1
40	2	1	40	2	11	20	2	1	40	2	1
40	3	1	40	3	3	20	3	1	40	3	1
20	1	17	20	1	4	40	1	1	20	1	1
20	2	1	20	2	2	40	2	1	20	2	8
20	3	1	20	3	0	40	3	1	20	3	1
40	1	65	40	1	3	40	1	1	40	1	3
40	2	1	40	2	10	40	2	1	40	2	5
40	3	8	40	3	5	40	3	1	40	3	1

[1]Personal communication from Ministry of Environment, British Columbia, Canada, 1978.
[2]Personal communication from the Tennessee Valley Authority, Muscle Shoals, Alabama, USA, 1974.
[3]From: Oklahoma Water Resources Board, Oklahoma City, Oklahoma. Contract DACW 56-79-M-0192, Tulsa District, U.S. Army Corps of Engineers, 1978.
[4]From: Water Resources Board, Fort Cobb Conservancy District, Report No. 68, Ft. Cobb, Oklahoma, 1976.

TABLE 2. STEPWISE REGRESSION COEFFICIENTS FOR ESTIMATED RESIDUE IN PARTS PER BILLION (PPB) FOR RATE OF APPLICATION OF HERBICIDE SEASON OF GROWTH IN DAYS, VOLUME DILUTION IN ACRE FEET, DEPTH OF WATER AS MEAN DEPTH AND TIME AFTER APPLICATION IN DAYS.

Variables	0 Y-Intcpt	1 Rate	2 Season	3 Volume	4 Depth	5 Days
Step						
0	9.9271*[1]	–.1063	–.3183	8.3891	.0865	–.1250
1	71.9128*	–.0203	–.3183*	–4.4481	–.2407	–.1250
2	111.2802*	.0130	–.4561*	–4.4481*	–.2633	–.1250
3	113.9088*	.0130*	–.4674*	–4.7577*	–.2612	–.1250

[1]Regression coefficients for variables in the equation are indicated by an asterisk.

The estimated 2,4-D residues (ppb) for a minimal spread of values in the United States are given in Table 3.

It is apparent from the matrix analysis that chemical residues expected from the application of 2,4-D in large reservoirs are not significantly different. The standard rate of application from 20 to 40 lbs acid equivalent per acre did not produce residues above the tolerance level of 100 ppb.

LITERATURE CITED

1. Weldon, L. W., R. D. Blackburn and D. S. Harison. 1969. Common Aquatic Weeds. Agricultural Handbook No. 352 USDA, Agricultural Research Service, Florida Agricultural Experiment Station; and the U.S. Army Corps Engineers, Government Printing Office, Washington, D.C.
2. Lee, G. F. 1970. Eutrophication. University of Wisconsin Press, Madison, Wisconsin.
3. Gangstad, E. O. 1971. Aquatic plant control program. Hyacinth Control J. 9:46-48.
4. Gangstad, E. O. 1972. Herbicidal control of aquatic plants. J. of the Sanitary Engineering Division, ASCE. April 1972 pp. 397-406.
5. Gangstad, E. O. 1978. Weed control methods for river basin management, CRC Press Inc., Boca Raton, Florida. 232 pp.
6. Whitney, E. W., A. B. Montgomery, E. C. Martin and E. O. Gangstad. 1973. The effects of a 2,4-D application on the biota and water quality in Currituck Sound, North Carolina. Hyacinth Control J. 11:13-18.
7. Bartley, T. R. and E. O. Gangstad. 1974. Environmental aspects of aquatic plant control. Journ. of the Irrigation and Drainage Division ASCE. Sept. 1974 00. 231-244.
8. Gangstad, E. O. 1978. Weed Control Methods for River Basin Management, CRC Press Inc., West Palm Beach, Florida.
9. Mackenthun, K. M. 1965. Nitrogen and Phosphorus in Water. U.S. Department of Health, Education and Welfare, Division of

TABLE 3. ESTIMATED VALUES FROM MATRIX ANALYSIS OF 2,4-D RESIDUES IN PARTS PER BILLION (PPB), LENGTH OF GROWING SEASON IN DAYS, VOLUME DILUTION IN 1000S OF ACRE FEET OF WATER, AND RATE OF APPLICATION IN LBS. ACID EQUIVALENT OF HERBICIDE PER ACRE.

Season (days)	Volume (ac-ft 1000′)	Rate (lbs/ac)	Residue (ppb)
150	100	20	34.5
		40	34.8
		80	35.3
	1,000	20	29.8
		40	30.0
		80	30.6
	10,000	20	25.0
		40	25.3
		80	25.8
200	100	20	11.2
		40	11.4
		80	12.0
	1,000	20	6.4
		40	6.7
		80	7.2
	10,000	20	1.7
		40	1.9
		80	2.4
250	100	20	0.0
		40	0.0
		80	0.0
	1,000	20	0.0
		40	0.0
		80	0.0
	10,000	20	0.0
		40	0.0
		80	0.0

Water Supply and Pollution Control. U.S. Government Printing Office. Washington, D.C.

10. Morris, Kenneth and Ron Jarman. 1981. Evaluation of water quality during herbicide applications to Kerr Lake, Oklahoma. Aquatic Plant Manage. 19:15-18.
11. Tennessee Valley Authority. 1972. Environmental Statement: Control of Eurasian watermilfoil (*Myriophyllum spicatum* L.) in TVA reservoirs. Tennessee Valley Authority; Chattanooga, Tenn.
12. Wojtalik, T. A., T. F. Hall and L. O. Hill. 1971. Monitoring ecological conditions associated with wide-scale applications of DMA 2,4-D to aquatic environments. Pesticides Monitoring Jour. 4:184-203.