MEASUREMENT OF THE REAERATION COEFFICIENTS OF THE NORTH FORK LICKING R1VER AT UTICA, OHIO BY RADIOACTIVE TRACERS

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CONVERSION FACTORS

Factors for converting inch-pound units to the International System of Units (SI) are given below:

To convert from	To	Multiply by
inch (in)	millimeter (mm)	25.40
foot (ft)	meter (m)	.3048
mile (mi)	kilometer (km)	1.609
square foot (ft^2)	square meter (m^2)	.0929
square mile (mi^2)	square kilometer (km^2)	2.590
cubic foot per second (ft^3/s)	cubic meter per second (m^3/s)	.02832
foot per second (ft/s)	meter per second (m/s)	.3048
foot per mile (ft/mi)	meter per kilometer (m/km)	.1894

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ABSTRACT

Reaeration coefficients of the North Fork Licking River at Utica, Ohio were measured by the radioactive-tracer method. The tests were conducted on a 2.1-mile reach on September 23 and October 7, 1981, during low-flow conditions. Krypton-85 gas and tritium were the radioactive tracers, which were used in conjunction with rhodamine-WT dye.

The reaeration coefficients determined on September 23 were 3.09 $days^{-1}$ (subreach 1-2) and 3.32 $days^{-1}$ (subreach 2-3). On October 7, the values were 2.04 $days^{-1}$ and 2.23 $days^{-1}$ respectively.

INTRODUCTION

Reaeration is the physical absorption of oxygen from the atmosphere into a body of water. In streams, reaeration is mainly a function of turbulence due to flow and channel morphology. It is the only persistent long-term mechanism of dissolved-oxygen replenishment in streams. The reaeration coefficient (K_2) is the rate constant defining this process. Therefore, a reliable estimate of the reaeration coefficient is of singular importance in determining the waste-assimilation capacity of streams.

Reaeration coefficients may be estimated from a number of equations or may be measured in the field. Two field methods used for measuring reaeration coefficients are the radioactive and hydrocarbon-gas tracer methods. Comparison tests have indicated that coefficients determined by either of these methods are far more accurate than those estimated by predictive equations, (Rathbun and Grant, 1978).

A study was done by the U.S. Geological Survey, in cooperation with the Ohio Environmental Protection Agency, to compare reaeration coefficients of the North Fork Licking River at Utica, Ohio, measured by the radioactive and hydrocarbon-gas tracer methods. However, because of equipment failure, only the results of the radioactive tracer experiments are reported. The study was made on a 2.1-mile reach of the North Fork Licking River on September 23 and October 7, 1981, during low-flow conditions.

ACKNOWLEDGEMENT

The author acknowledges with gratitude and thanks Carolyn J. Oblinger Childress, U.S. Geological Survey, for analyzing the radioactive tracer samples.

DESCRIPTION OF STREAM REACHES

The tests were made on the North Fork Licking River at Utica, Ohio. The entire study reach was 2.1 miles long, extending 0.9 mile upstream and 1.2 miles downstream of the Utica sewage disposal plant (fig. 1). There were no significant tributaries in this reach. The only discharger was the sewage disposal plant.

The North Fork Licking River is a pool-and-riffle type of stream that has moderately steep banks covered by trees and brush. The streambed consists mainly of cobbles, small rocks,

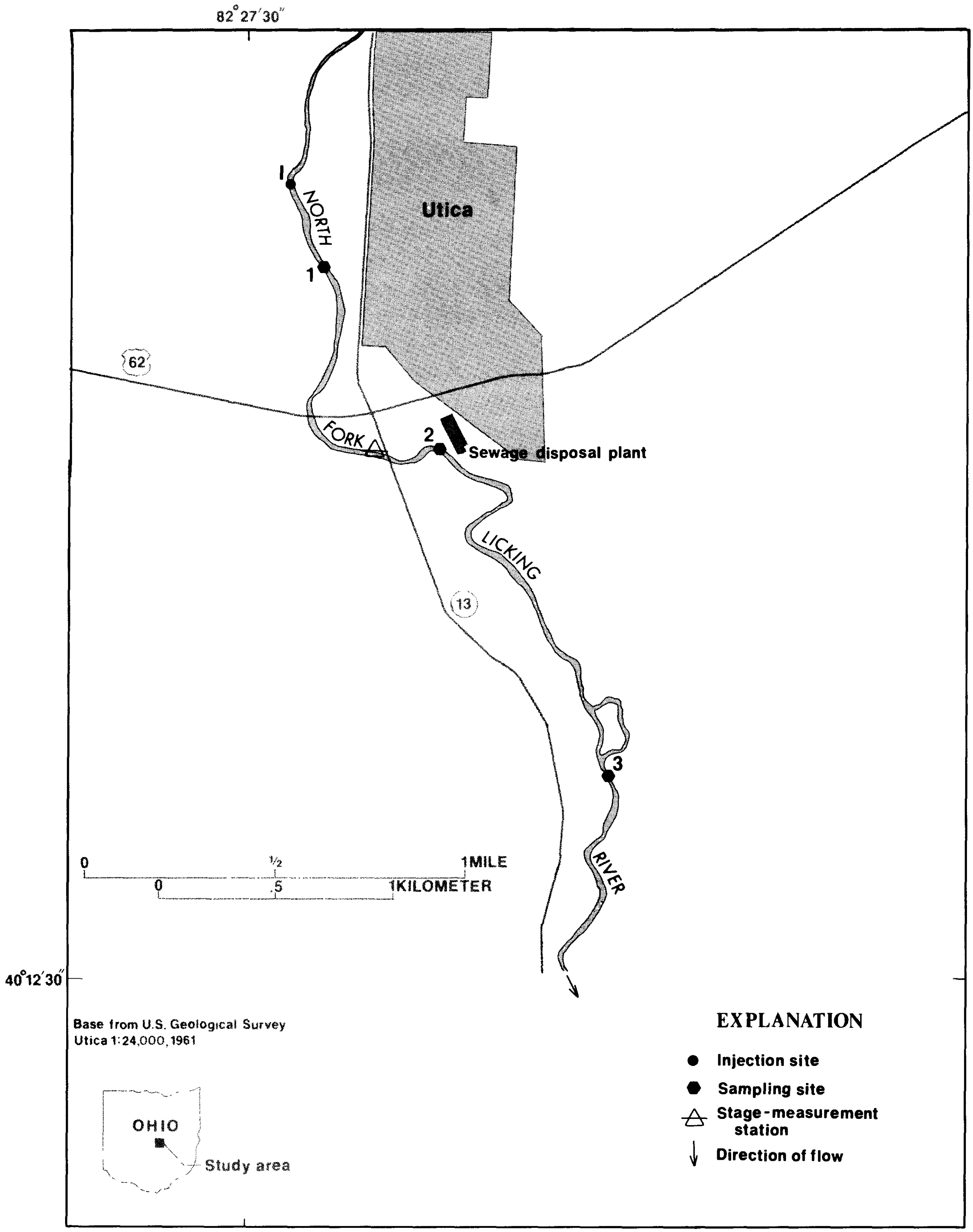

Figure 1.--Location of study area and sampling sites.

sand, and gravel. The water depth during the studies ranged from less than 0.5 foot in riffles to several feet in pools. Average channel slope for the study reach is 8.2 feet per mile. The stream meanders through the small rural community of Utica and through agricultural land.

The stream discharge at Utica on September 23 was about 20 ft^3/s (cubic feet per second); the average velocity (for the entire study reach) was 0.25 ft/s (feet per second). Water temperature ranged from 12.4 to 14.1°C. On October 7, the stream discharge was about 9 ft^3/s and the average velocity was 0.12 ft/s. Water temperature ranged from 10.6 to 12.5°C. These discharges are approximately 15 and 7 percent, respectively, of the average flow for the period of record (1939-1948, 1969-1980) for the North Fork Licking River at Utica (U.S. Geological Survey, 1980). Stream data are presented in tables 1 through 4.

METHODS OF STUDY

Radioactive Tracer Method

The mass transfer rate for krypton-85 is related to the transfer rate for oxygen by a constant (Tsivoglou, 1967). The method involves an instantaneous injection of an aqueous solution of krypton-85 gas, tritium as tritiated water, and rhodamine-WT dye. The krypton is the tracer for oxygen and tritium is the dilution/dispersion tracer. The rhodamine dye indicates when to sample for the gases. The procedure is described in detail by Tsivoglou (1967, 1974) and Neal (1979).

The desorption coefficient for krypton (K_{kr}) is calculated from the following equation:

$$K_{kr} = \frac{1}{t_d - t_u} \log_e \left(\frac{R_u}{R_d}\right) \qquad (1)$$

where t is the time of travel for the peak gas concentration, R is the ratio of peak krypton counts to peak tritium counts, and the subscripts u and d indicate the upstream and downstream sampling points, respectively. K_{kr} is converted to the absorption coefficient for oxygen (K_2) by

$$K_{kr}/K_2 = 0.83 \qquad (2)$$

Table 1.--Time of travel, discharge, water temperature, and krypton/tritium ratios for North Fork Licking River, September 23, 1981

[Time of radioactive tracer injection: 0705]

Site	Time of travel from injection site to dye peak (min)	Discharge (ft^3/s)	Water temperature (°C)	Krypton/tritium ratio
1	51	19.0	12.4	5.14
2	403	19.4	14.0	3.02
3	782	20.2	14.1	1.61

Table 2.--Length of reach, water velocity, and wind velocity on September 23, 1981, North Fork Licking River

	Length of reach (ft)	Water velocity (ft/s)	Average wind velocity for study period (mi/h)
Reach 1-2	4,652	0.22	1.53
Reach 2-3	6,336	.28	1.53

Table 3.--Time of travel, discharge, water temperature, and krypton/tritium ratios for North Fork Licking River, October 7 and 8, 1981

[Time of radioactive tracer injection: 0740]

Site	Time of travel from injection site (min)	Discharge (ft^3/s)	Water temperature (°C)	Krypton/tritium ratio
1	110	8.52	12.1	0.2649
2	867	8.82	12.5	.1262
3	1,582	8.90	10.6	.0595

Table 4.--Length of reach, water velocity, and wind velocity on October 7 and 8, 1981, North Fork Licking River

	Length of reach (ft)	Water velocity (ft/s)	Average wind velocity (for study period) (mi/h)
Reach 1-2	4,652	0.10	2.11
Reach 2-3	6,336	.15	2.11

Reaeration coefficients are adjusted to a common temperature of 20°C by the equation

$$K_{2(20^{o})} = K_{2(T)}(1.0241)^{20-T} \quad (3)$$

where T is the water temperature in degrees Celsius. The factor of 1.0241 was determined by Elmore and West (1961).

EXPERIMENTAL PROCEDURE

Injection

A solution of rhodamine-WT dye and water was injected by a constant-rate metering pump for 20 minutes into the stream at the center of flow. Dye injection rates were estimated by the equations from Rathbun (1979). At the midpoint of the dye injection period, a bottle containing an aqueous mixture of krypton-85 and tritium was submerged at the dye injection point and the tracers released.

Sampling

Samples for dye and radioactive tracers were collected at three points downstream of the injection site (fig. 1). At each site, samples were collected at the center of flow. Samples for radioactive gas analyses were collected by means of displacement type samplers and 40-ml (milliliter) borosilicate glass vials that had Teflon[1] septa screw caps. Dye samples were collected in 30-ml vials and analyzed in the field with a Turner model 10 fluorometer. Sampling was continued at each site long enough to define completely the dye concentration-versus-time curves. Discharge measurements were also made at all three sites on the day of the study.

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[1]The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Sample Analyses

Samples for krypton and tritium were analyzed by the U.S. Geological Survey by means of a liquid scintillation counter and the technique described by Neal (1979). Three samples from each site, taken at the time of the peak dye concentration, were selected for analysis. Three replicates of each sample were prepared; all samples were then counted three or four times for 10 to 50 minutes depending on the level of radioactivity expected.

RESULTS

Dye concentration-versus-time curves for the September and October tests are presented in figures 2 through 4 and 5 through 7, respectively (figures are at back of report). Time of travel between sites was determined from the times of the peak dye concentration at each sampling site, time being measured from the midpoint of the injection of the tracers. These time-of-travel data are listed in tables 1 and 3.

The reaeration coefficients (K_2) are presented in table 5. The coefficients were determined by equations 1, 2, and 3, and the krypton/tritium ratios listed in tables 1 and 3. The coefficient of 2.04 $days^{-1}$, which was determined for reach 1-2 on October 7, is 34 percent lower than the coefficient of 3.09 for the same reach on September 23. The stream discharge and the mean velocity for this reach were 55 percent lower on October 7. The coefficient of 2.23 $days^{-1}$ for reach 2-3 on October 7, was 33 percent lower than the coefficient of 3.32 $days^{-1}$ on September 23, when the discharge and velocity were 55 and 46 percent lower respectively.

Table 5.--Measured reaeration coefficients (radioactive tracer method) corrected to 20°C, North Fork Licking River at Utica, Ohio

	Reaeration coefficients, K_2, at 20°C, in $days^{-1}$	
	September 23, 1981	October 7, 1981
Reach 1-2	3.09	2.04
Reach 2-3	3.32	2.23

REFERENCES CITED

Elmore, H. L., and West, W. F., 1961, Effect of water temperature on stream reaeration: American Society of Civil Engineers, Proceedings, Journal of the Sanitary Engineering Division, v. 87, no. SA-6, p. 59-71.

Neal, L. A., 1979, Method for tracer measurement of reaeration in free-flowing Texas streams: Law Engineering Testing Company, 65 p.

Rathbun, R. E., 1979, Estimating the gas and dye quantities for modified tracer technique measurements of stream reaeration coefficients: U.S. Geological Survey Water-Resources Investigations 79-27, 42 p.

Rathbun, R. E., and Grant, R. S., 1978, Comparison of the radioactive and modified techniques for measurement of stream reaeration coefficients: U.S. Geological Survey Water-Resources Investigations 78-68, 65 p.

Tsivoglou, E. C., 1967, Tracer measurement of stream reaeration: Federal Water Pollution Control Administration Report, 86 p.

----- 1974, The reaeration capacity of Canandaiqua outlet, Canandaiqua to Clifton Springs: New York State Department of Environmental Conservation, Project no. C-5402, 79 p.

U.S. Geological Survey, 1980, Water Resources Data for Ohio, v. 1, 619 p.

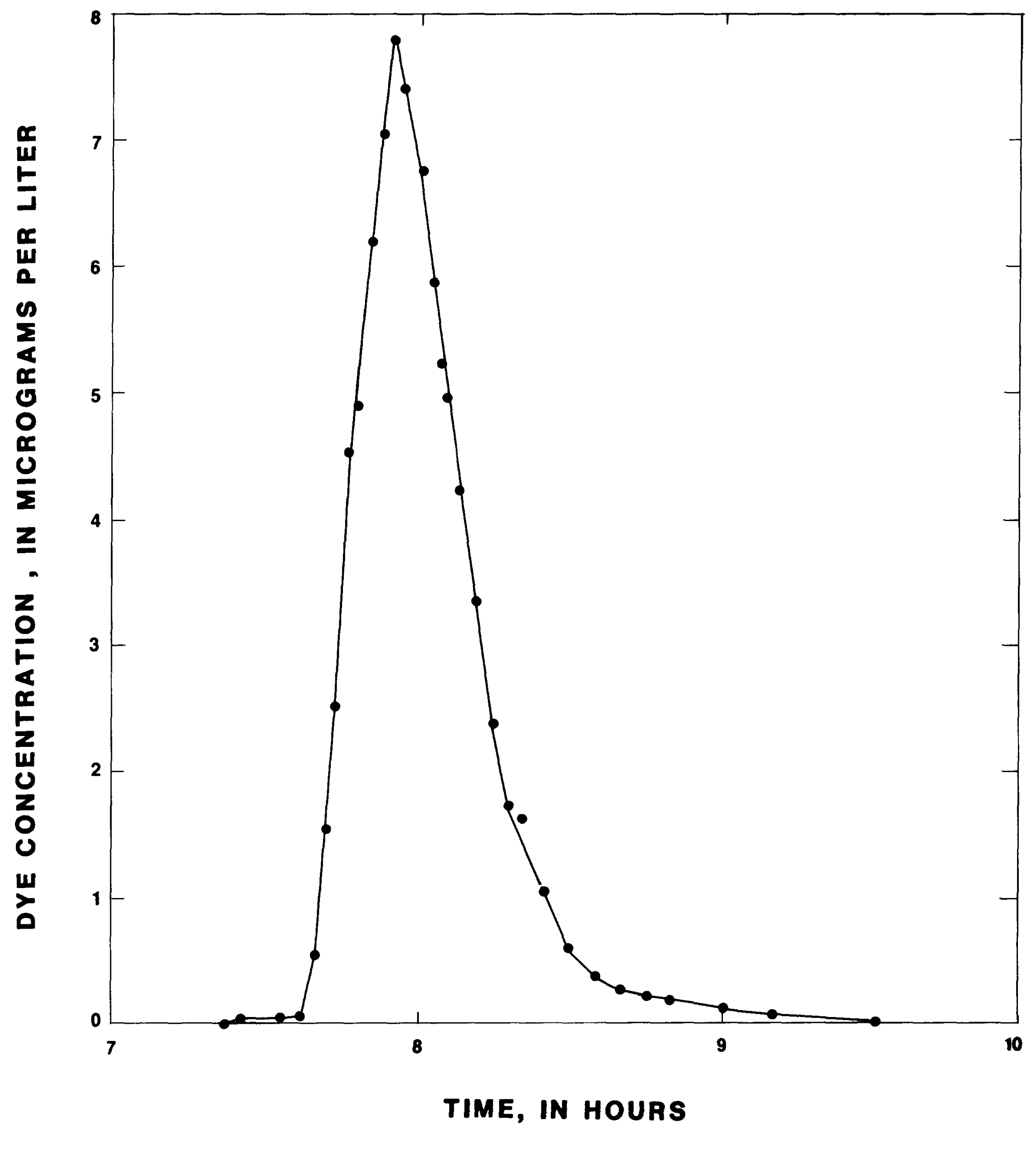

Figure 2.--Concentration of rhodamine -WT dye as a function of time at site 1, North Fork Licking River, September 23, 1981 (dye injected 0655-0715).

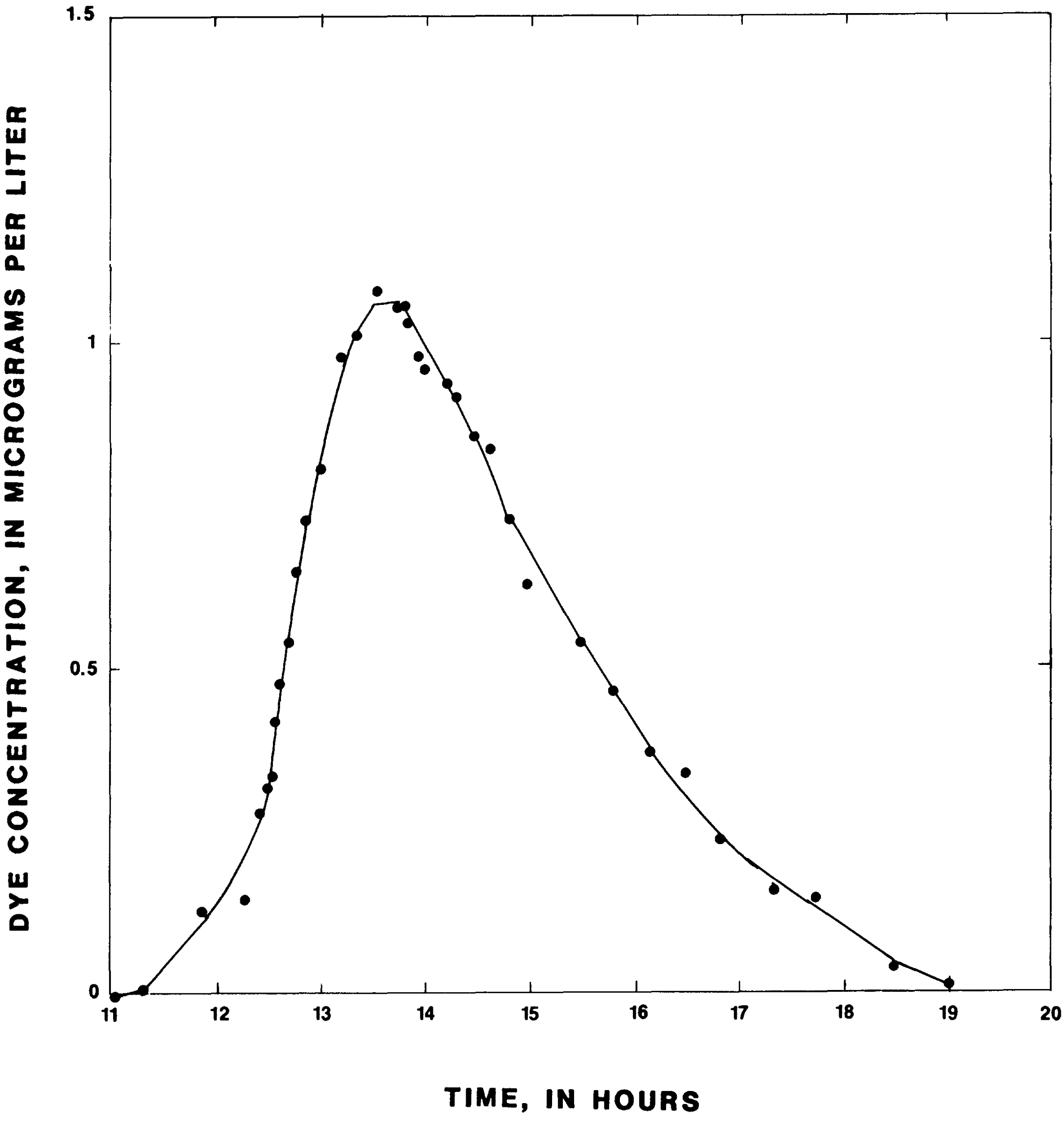

Figure 3. --Concentration of rhodamine-WT dye as a function of time at site 2, North Fork Licking River, September 23, 1981 (dye injected 0655-0715).

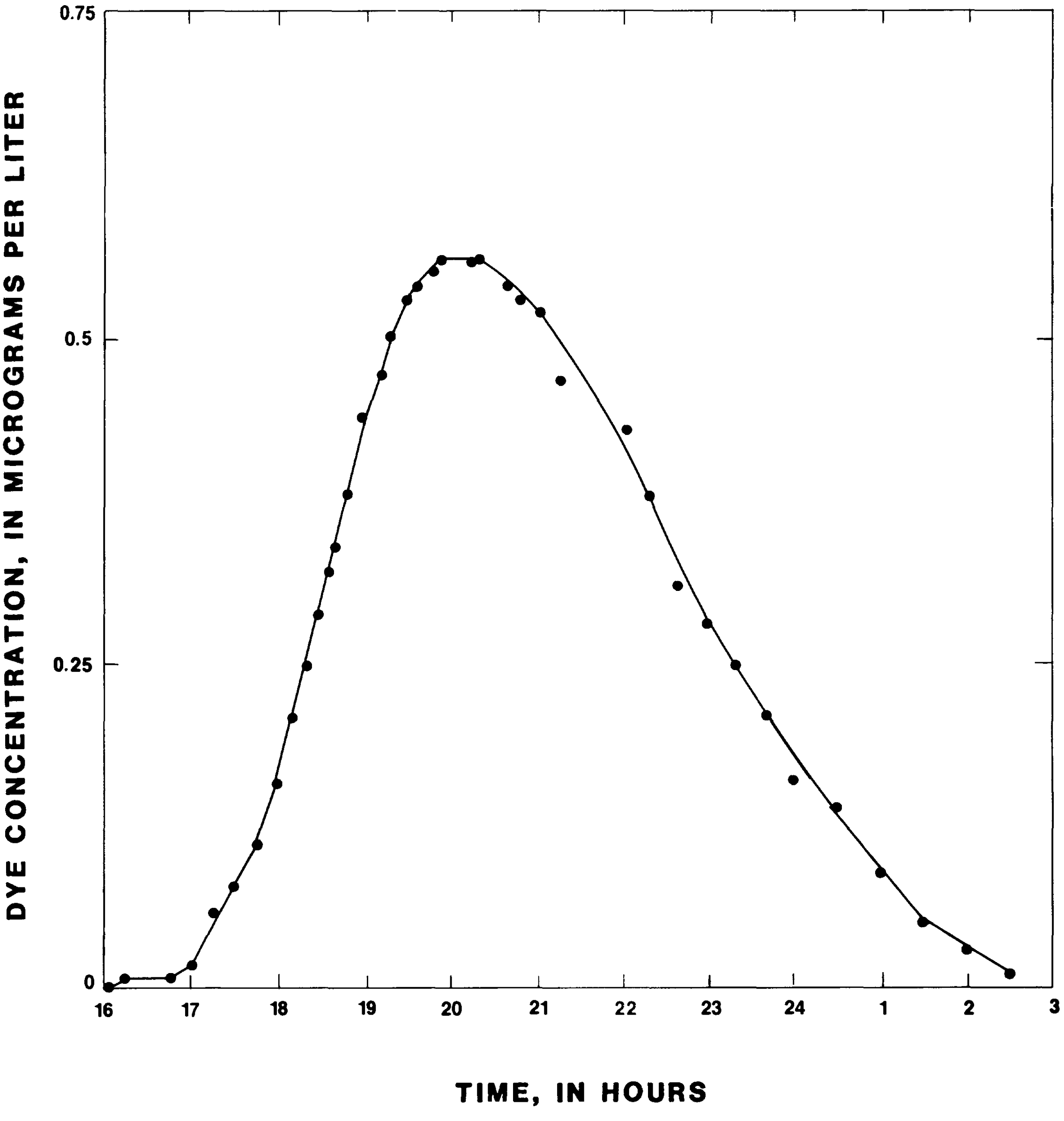

Figure 4.--Concentration of rhodamine-WT dye as a function of time at site 3, North Fork Licking River, September 23 and 24, 1981 (dye injected 0655-0715).

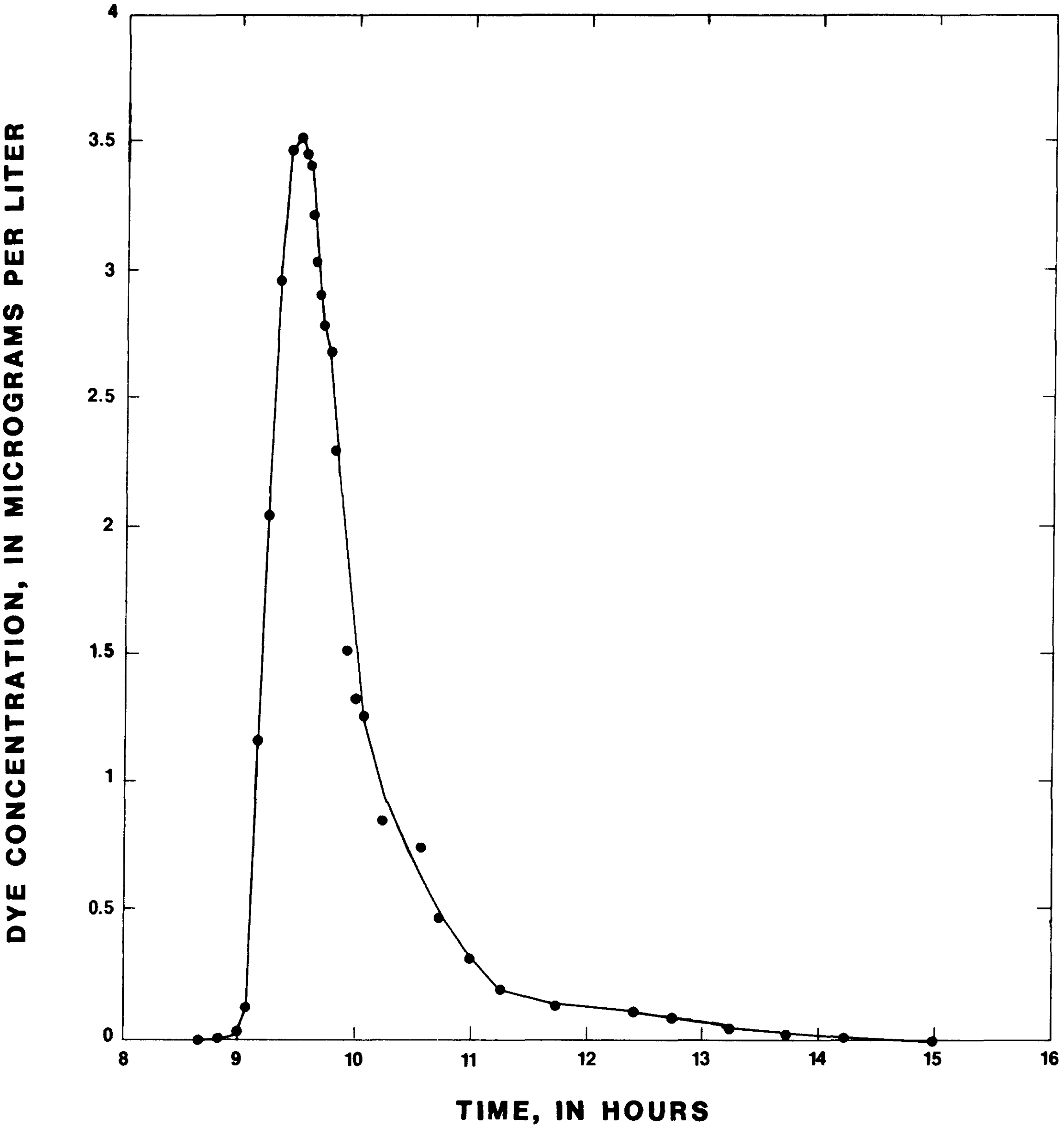

Figure 5.--Concentration of rhodamine-WT dye as a function of time at site 1 , North Fork Licking River, October, 7, 1981 (dye injected 0730-0750).

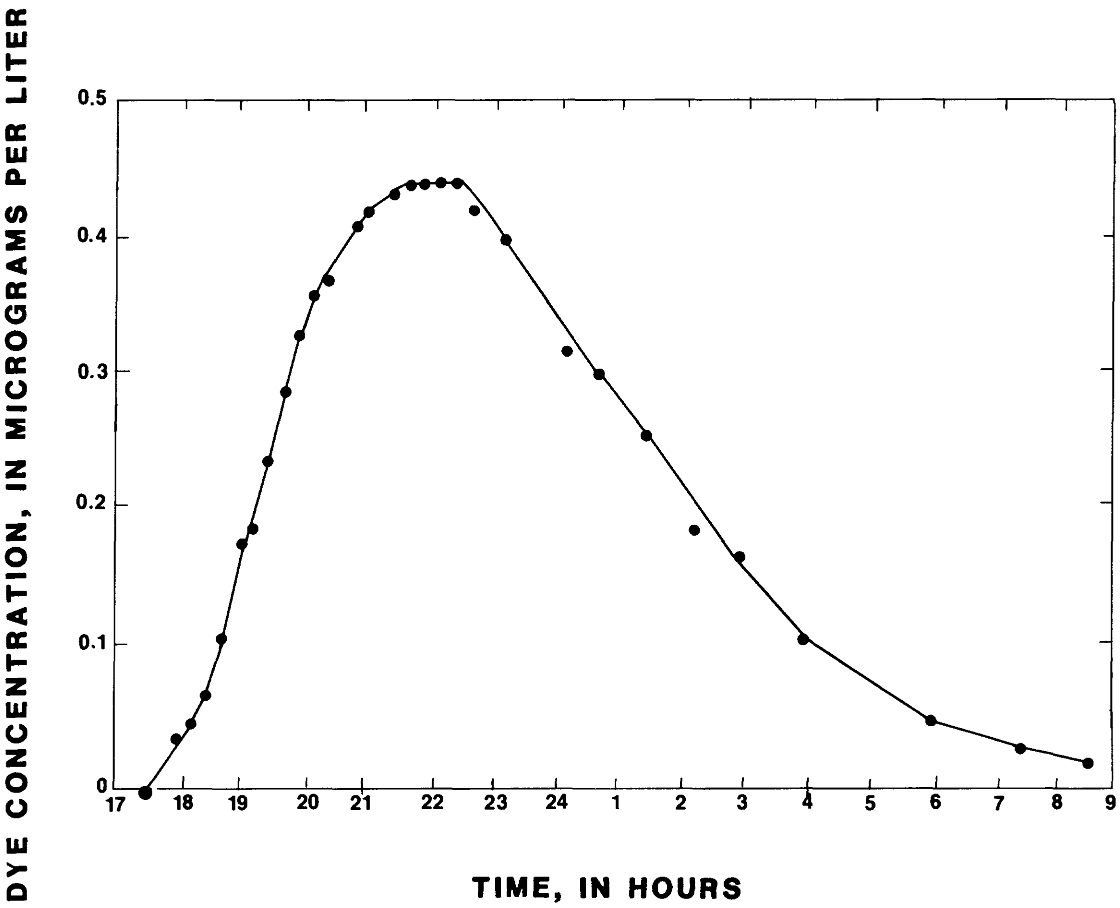

Figure 6.--Concentration of rhodamine-WT dye as a function of time at site 2, North Fork Licking River, October 7 and 8, 1981 (dye injected 0730-0750).

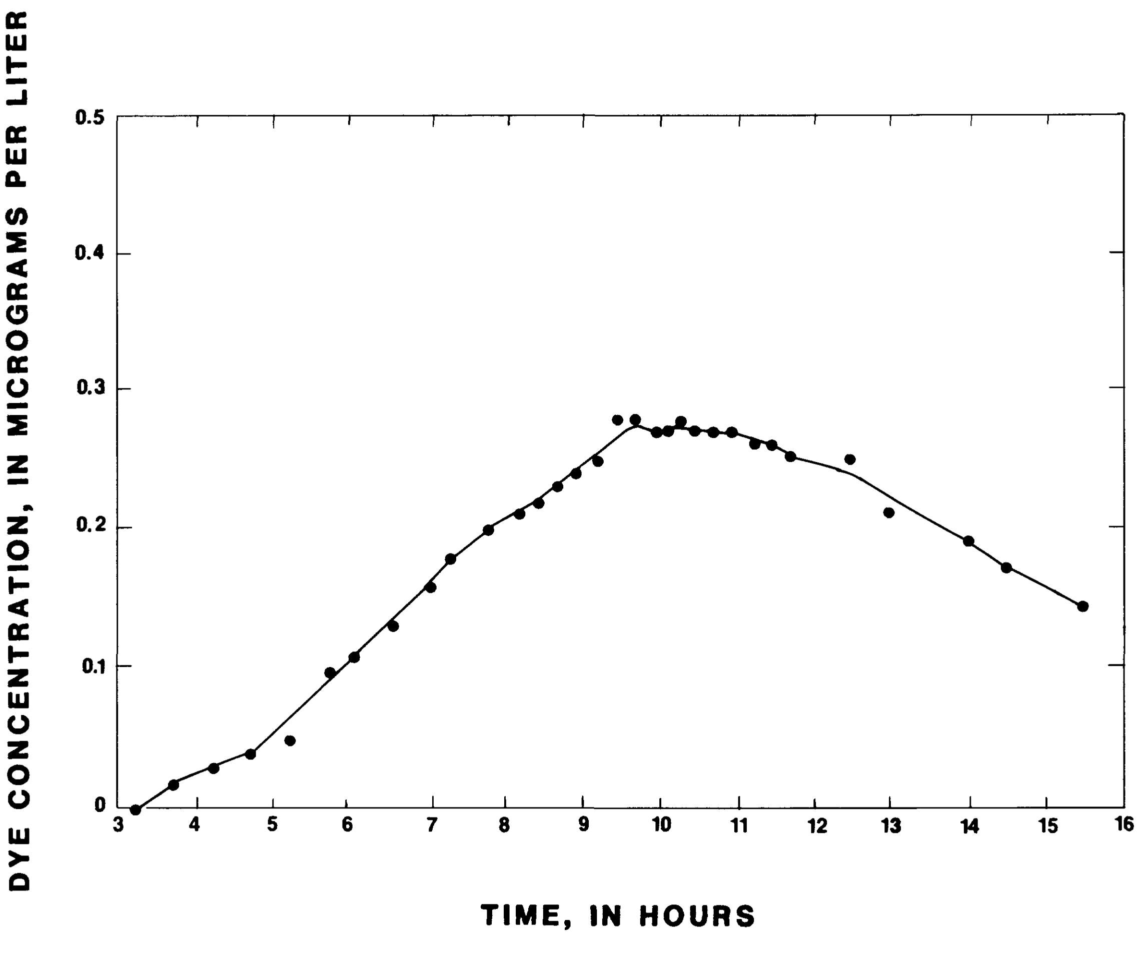

Figure 7.--Concentration of rhodamine-WT dye as a function of time at site 3, North Fork Licking River, October 8, 1981 (dye injected 0730-0750).

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