TURNER DESIGNS
Reliable Instruments for an Unreliable World

Technical Note:
Fluorometric Facts: Fluorometry in the Water Pollution Control Plant

CONTENTS

Foreword

Knowing wastewater flow patterns exactly can greatly reduce control plant operating budgets. The flexibility of dye-dilution measurements, from conceptual design to plant troubleshooting, can also reduce your capital investment.

A rugged field-proven fluorometer can be used to:

- Localize infiltration.
- Accurately calibrate any type of flowmeter.
- Measure pump performance on site.
- Determine efficiency of settling tanks and pinpoint hydraulic "short-circuits".
- Determine chlorine contact chamber efficiency.
- Measure effluent dilution and flow pattern in the receiving water.
- Give a continuous indication of nutrients and toxic materials in the effluent.
- Study cross contamination.

Localizing Infiltration

Quantitative flow measurement from manhole to manhole can be used to determine groundwater infiltration or surface water inflow into a sanitary sewer system. Infiltration rates are determined during periods of high groundwater and no rainfall. Surface water inflow must be determined during actual or simulated rainfall.

Conventional flow measurement techniques include dipsticking and an estimate of flow velocity or the use of a weir installation. Both methods offer limited accuracy when the flow is limited, and become nearly useless when the sewer system is surcharged.

Automatic-recording, level-measuring devices are available, with and without specially shaped flumes. However, these are limited in accuracy, as they depend on ideal manhole hydraulics, which rarely exist in practice.

Dye-dilution techniques, however, can give an accuracy of ±2%. Using this method, dye is continuously injected into the sanitary sewer system and the dye dilution is determined downstream. Accuracy is maintained over the entire range of flows, including both low and surcharged levels.

Field time is reduced to a minimum, and there is no need to crawl into a manhole. All you need is a small sewage sample, which can be conveniently measured in the field or brought back to the central laboratory.

This technique was pioneered by Smith and Kepple in Anderson, California (Ref. 1). Precise directions on

flow measurement in sanitary sewers are available (Ref. 2 & 16).

Calibrating Flow Meters

Measurements can be made on site, quickly and easily, with an accuracy of close to ±2%. If you want an accuracy closer to ±1%, well-stirred laboratory temperature baths and matched glassware will all improve the accuracy of readings of a digital fluorometer.

In the past, precise knowledge of flow in water pollution control plants was less crucial than today. Now, as individual municipal primary treatment plants are combined and upgraded into secondary and even tertiary plants, flowmeter accuracy assumes increasingly greater economic importance. Operating costs are shared on a sewage-volume basis between the various municipalities that form the large sewage system. Routine calibration of flow meters using dye-dilution techniques can simultaneously avoid accounting problems and save capital investment. As the system grows, older flow meters of questionable accuracy can be precisely calibrated on the spot and retained for use.

Lift Station Calibration

Traditionally, municipalities request on-site proof of large lift pump performance. With dye dilution techniques, on-site proof of performance is easily made. This is important both after installation, to ensure working order, and periodically throughout the life of the pump to determine when repairs will save money through increased efficiency.

A complete report on pump performance tests run at the Morris Forman Waste Water Treatment Plant in Louisville, KY has been written (Ref. 3). Pump flows of 89.9 to 120.5 MGD were checked over a dynamic head range of 70-100 feet. The report also covers validation tests of the dye-dilution technique in flow measurements at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota. Results were compared with volumetrically measured flows over a range of 50,000 to 80,000 GPM (72-115 MGD).

Efficiency of Settling Tanks

It appears that more could be done to improve the quality of effluent water from water pollution control plants by relatively minor changes in settling tanks than by any other method. A paper entitled "Folklore in the Design of Final Settling Tanks" (Ref. 4) brings this point home.

One of the key points in the design of settling tanks is a smooth, uniform flow from entry to exit. For example, if a settling tank has a two-hour detention time and a slug of dye is dumped into the inlet line, no dye should appear for nearly two hours. Then all the dye should pass through the outlet in a short period of time.

Mixing occurs due to kinetic energy in the water entering the settling tank, and channeling and velocity increase as water leaves the settling tank. In the real world, settling tanks may behave as if they are mixing tanks, where dye appears almost immediately at the output, then decays exponentially. They may also behave as if they were "short-circuited". The dye appears far too quickly at the output, and dies away quite quickly, with an extended "tailing-off" period. This indicates that the tank has a direct path from inlet port to the weir. In this case, a large part of the volume of the tank is essentially unused.

Using dye techniques, minor changes in baffling at the intake and outlet can cause major changes in settling tank performance (Ref. 5 & 6).

Efficiency tests of your settling tank may be made quickly and on the spot. Using "grab" samples, the course of the water through the tank can be visualized. You can quickly test changes in baffling.

Crosby (Ref. 15) points out that seven to ten days of on-site study (including dye-tracer profiles) of activated sludge secondary clarifiers, and similar time for data reduction and analysis, usually leads to obvious corrective procedures. At the time, modifications had been completed in four plants. All were successful in significantly reducing effluent total solids (and associated BOD) by 31%.

Chlorine Contact Chamber Efficiency

The efficiency of chlorine contact chambers may be checked in the same way as settling tanks.

Studies in California (Ref. 7) show that mean contact time in chlorine contact chambers varies from 30-80% of the theoretical time. Proper baffling and location of inlet and discharge lines can undoubtedly improve efficiency, with resultant savings in chlorine and reduction in residual chlorine in the effluent.

Reduction in residual chlorine may be highly desirable, as excessive residual chlorine kills phytoplankton in the receiving water (Ref. 8, Ref. 9, pg 34).

Interruption of chlorine flow is necessary only during the short time required to inject the dye (Ref. 10). Except at the point of injection of the chlorine, chlorine levels are so low that they do not affect the dye.

Effluent Dilution and Diffusion

Dilution and diffusion is the subject of a companion monograph entitled "Circulation, Dispersion and Plume Studies" (available from Turner Designs).

More recent articles include a study of Netarts Bay, Oregon (Ref. 11), and a study off the east coast of Florida (Ref. 12). In the Netarts Bay study, dye techniques were used to determine the optimum location of a proposed outfall. The study, complete and detailed, recommended an acceptable location, but suggested an unusual proposal: to discharge at a second location, but only during the two hours following high tide. In the Florida study, unusual wind conditions and proximity to the Gulf Stream caused the effluent plume to bend back toward the shore. Coliform count and dye concentration correlated well. As a result, the outfall was extended to reduce the risk of beach contamination.

In a communication from Mr. Kenneth Rubin of Wapora, Inc., we learned that dye studies have been used to follow the thermal plume from a power plant discharging into a shallow bay. Varying climatic and tidal conditions made it difficult to rely on the conventional use of temperature profiles to follow the thermal plume.

This same group has used conventional dye-tracing methods to provide ground truth data for aerial infrared photography. The aerial photographs were then used to determine two-dimensional diffusion constants. These constants were then used in a flushing model for the Anclote Anchorage, north of St. Petersburg, Florida.

In a communication from Dr. P.P. Paily of NALCO Environmental Services, we learned that they have used dye-tracer studies to determine the part of the Mississippi River affected by the cooling water intake of a nuclear power plant. This data was used to supplement larval entrainment studies to evaluate the impact of station operation on fisheries. They have also used dye-dilution techniques to determine dilution and dispersion of drilling fluid at an offshore drilling site in Cook Inlet, Alaska.

Continuous Indication of Nutrients and Toxic Materials in Effluents

When the nutrient level in the receiving water goes up, phytoplankton will grow in response. The presence of toxic materials causes the phytoplankton to die.

Fluorometric techniques may be used to measure phytoplankton, as all phytoplankton contains chlorophyll, a fluorescent material. These techniques are the subject of a companion monograph, entitled "Chlorophyll and Pheophytin", (available free from Turner Designs) which gives a detailed description of these techniques, with extensive references.

The references to eutrophication studies in receiving waters, and of the effect of toxic materials on phytoplankton will be particularly interesting to water pollution control plant operators.

Cross Contamination

Cross-contamination covers a multitude of problems, depending on the nature of the water pollution control plant and collection system.

An obvious problem is in collection systems designed to segregate polluted water, depending on the nature of the pollutant. This is particularly pertinent to large industrial or service facilities, built up or added to over a period of years. Often in such a situation, unauthorized connections are made to the nearest sewer, rather than to the correct one. Use of fluorescent dyes and a fluorometer can positively identify such interconnections.

Leaks can also contaminate nearby wells. In rural situations, it has been common practice for years to flush a little fluorescein dye down a toilet. The neighbor's well is then checked for several days for a tell-tale green coloration.

In large systems and where it takes considerable time for the water to reach the suspected point of contamination, the use of Rhodamine WT dye and a fluorometer is quite economical. The instrument is far more sensitive than the eye, allowing the use of a much smaller amount of dye. The instrument also has continuous sampling and data logging capability, saving operator hours.

Where contamination at multiple points is suspected, automatic samplers normally used for sewage and pollution studies may be used to obtain samples at regular intervals. These can be brought to a central laboratory for analysis on a single fluorometer.

Several references to the use of fluorescent dyes for following underground water transport are found in the companion monograph "Circulation, Dispersion and Plume Studies".

Studies brought to our attention include:

1) The use of Rhodamine WT and other fluorescent dyes to follow water in a karst (limestone) area for distances of up to 30 kilometers and requiring up to 16 days after dye injection to reach the recovery site (Ref. 13).

2) The use of Rhodamine WT in England to check the interconnection of sink holes with springs used as potable water sources. Connection was established over a distance of six kilometers, with a delay time of two-and-a-half days (Ref. 14).

These results were obtained under ideal conditions for underground use of dye tracers, as surface area was low and flow rate high.

Note that dyes are vulnerable to adsorption or ion-exchange when percolating through sub-surface materials. Humic materials are particularly suspect. Negative results might be found in such situations.

We assume, however, that if the dye is lost, so are the cross contaminating harmful materials.

NOTES

References

1. (TD Lib. #0007) S.A. Smith, L.G. Kepple, "Infiltration Measure in Sanitary Sewers by Dye-Dilution Method," *Water and Sewage Works*, 58-61 (Jan. 1972).

2. "Flow Measurements in Sanitary Sewers by Dye Dilution," Turner Designs, (Mar. 1994).

3. (TD Lib. #0415) W. Morgan, D. Kempf, R.E. Phillips, "Validation of Use of Dye-Dilution Method for Flow Measurement in Large Open and Closed Channel Flows", presented at the Flow Measurement Symposium, National Bureau of Standards, (Feb. 1977).

4. (TD Lib. #0417) R.I. Dick, "Folklore in the Design of Final Settling Tanks," Journal of Water Pollution Control Federation, pgs. 633-644, (1976).

5. (TD Lib. #0265) R. Male, D.R. Basco, "A Dispersion Curve Study of Model Dredge Spoil Basins," C.D.S. Report No. 180, Dept. of Marine Resources (1974).

6. (TD Lib. #0288) J.R. Villemont, G.A. Rohlich, "Hydraulic Characteristics of Circular Sedimentation Basins," Progress Report, Research Grant WP-183, NIH, by Hydraulic and Sanitary Engineering Labs, University of Wisconsin (Jun. 1962).

7. (TD Lib. #0008) D.G. Deaner, "A Procedure for Conducting Dye-Tracer Studies in Chlorine Contact Chambers to Determine Detention Time and Flow Characteristics".

8. (TD Lib. #0341) L.D. Jensen, "Environmental Responses to Thermal Discharges from the Indan River Station, Indian River, Delaware," EPRI Publication 74-049-00-3 (1974).

9. (TD Lib. #0342) L.D. Jensen, "Second Workshop on Entrainment and Intake Screening," EPRI Publication 74-049-00-5.

10. (TD Lib. #0026) D.G. Deaner, "Effect of Chlorine on Fluorescent Dyes," Journal of Water Pollution Control Federation, 45:3, 507-514 (1973).

11. (TD Lib. #0337) S.L. Boley, L.S. Slotta, "Relevent Data Concerning Proposed Discharges of Domestic Wastes into Netarts Bay, Oregon," Oregon State University Sea Grant Program, ORESU-T-74-002 (1974).

12. (TD Lib. #0416) R.E. Stewart, "Unusual Plume Behavior from an Ocean Outfall off the East Coast of Florida," Journal of Physical Oceanography, 3:2, 241-243 (1973).

13. (TD Lib. #0388) P.L. Smart, D.I. Smith, "Water Tracing in Tropical Regions, the Use of Fluorometric Techniques in Jamaica," Journal of Hydrology, 30:179-195 (1976).

14. (TD Lib. #0321) T.C. Atkinson, D.I. Smith, "Rapic Groundwater Flow in Fisures in the Chalk: An Example from South Hampshire," Journal of Engineering Geology, 7:197-205 (1974).

15. (TD Lib. #1044) R.M. Crosby, "Making Clarifiers Work Better: The "Bubble Gum" Approach.

16. "Using the Turner Designs Model 10-AU Fluorometer to Perform Flow Measurements in Sanitary Sewers by Dye Dilution," (a monograph), Turner Designs, (Mar. 1994).