Introduction

Dye testing (eg. rhodamine, fluorescein) has long been an accepted and successful method in detecting failing septic systems.

This is usually done by placing dye into a toilet bowl, flushing several times, and then visually inspecting the area around the septic adsorption field for surface outbreak. The surface of the ground immediately above the septic system as well as the surface of the ground (and receiving waters) that are immediately down gradient from that septic system are visually monitored for several days. If surface outbreak does occur (when that dye is visually detected) then that septic system is in regulatory failure. (Knowles, personal communication)

Placing an Optical Brightener sampling device into a stream

Optical Brighteners are fluorescent white dyes that are added to almost all laundry soaps and detergents because clothing made from cotton fabrics naturally looks yellowish and drab. This occurs because cotton absorbs blue rays that are present in sunlight. When Optical Brightener is applied to cotton fabrics, they will absorb ultraviolet rays in sunlight and release them as blue rays. These blue rays will then interact with the yellowish color and give the garment the appearance of being “whiter than white”. Because the main commercial use of these dyes is in laundry detergents and textile finishing, Optical Brightener dyes are generally found in domestic waste waters that have a component of laundry effluent. Optical Brighteners can therefore enter the subsurface environment as a result of ineffective sewage treatment (Fay, Spong, and Alexander, 1995) .

Optical Brighteners are removed from underground waters by adsorption onto soil and organic materials, they are removed from surface waters by adsorption and by photo decay. Since adsorption is a critically important process in the performance of septic field systems, the recovery of Optical Brighteners in nearby waters (either surface or ground water) indicates ineffective natural cleansing of waste waters (Aley, 1991).

Fluorescent dyes (such as Optical Brightener) have been used extensively for tracing surface water and groundwater because of their low detection limits, ease and economy of detection, availability and safety. Fluorescent dyes have successfully been used for delineating otherwise unpredictable groundwater movement (Quinlan, 1981). Fluorescent dyes have also been used as adsorbing tracers in order to predict the possible breakthrough of pesticides in agricultural settings (Everts and Kanwar, 1994).

Because Optical Brighteners are fluorescent white dyes that absorb ultraviolet "U.V." light and fluoresce in the blue region of the visible spectrum, they can therefore be detected by use of a long wave fluorescent "U. V." or a "black" light.

Two Massachusetts groups, the Ipswich Coastal Pollution Control Committee and the Gloucester Shellfish Department / Shellfish Advisory Commission, have found that Optical Brightener testing when done in combination with a larger sampling program is a reliable indicator in helping to identify: faulty septic systems, sewage exfiltration, storm drain cross-connections, and human/animal waste differentiation.

This project links together key individuals of these two North Shore groups for the expressed purpose of producing an Optical Brightener Handbook that can then be used by other water quality monitoring groups.

Step 1: Getting Started

A. Sampling Plan

A sampling plan should be conducted before any sampling has begun. The following are special considerations that should be taken into account when formulating an Optical Brightener Sampling Plan.

1. Combining Optical Brightener sampling with other data

One should be very careful in drawing conclusions from Optical Brightener sampling alone. Optical Brightener sampling is infinitely more accurate and therefore much more useful when it is part of a larger sampling program. When conducting Optical Brightener sampling for marginal or failing septic systems, it is recommended that the monitoring plan also include information on:

a.) Rainfall - Quite obviously, there are fewer potential sources of contamination during dry weather than during wet weather. Rainfall data is therefore vital in being able to pin-point a source(s).

b.) Bacterial Sampling- Because Optical Brightener sampling only provides presence/ absence data, it is important to remember that in many instances, bacterial sampling is necessary to provide quantitative results about a pollution source. Quantitative results are required to determine the concentration of pollutants in a water sample to evaluate the relative contribution of a pollution source to water quality problems and to help guide pollution remediation and enforcement decisions.

c.) Flow data - Flow data is vital information in monitoring as well as in remediation because:

- Without water as a transport vehicle, waste water has no way of reaching and then impacting receiving waters from upland sources.
- Volume flows are needed when calculating bacterial loading. Bacterial loading is calculated by measuring flow in gallons per minute, the number of bacteria in a 100 ml portion taken from that source, and entering this

information into the formula: Bac/day = bac x Q x 54800 (where bac= bacterial concentration per 100ml of water and Q is gallons per minute) Kittrell, 1969. Bacterial loading calculations are used to figure the total number of bacteria per day that is being contributed by a source (or sources) to receiving waters and is critical in being able to compare the relative contribution of pollution sources. (As an example: a site which has a bacterial count of 240/100ml and a volume of 100 gallons per minute would have ten times the bacterial loading as a site that has a count of 2,400/100ml and a volume flow of only 1 gallon per minute.)

- Sometimes rainfall and high groundwater can dilute Optical Brightener dye to such a degree that it can not be detected through qualitative sampling.
- By profiling dry weather flow data, one is able to calculate periods of seasonally high and seasonally low groundwater tables.
- Because a high water table can sometimes cause substandard on-site septic systems to fail, there are instances where a sample will be repeatedly negative during low groundwater periods and yet positive during periods of high groundwater.
- It is advantageous to take flow measurements just prior to placement of the rigid O.B. sampling device.

d.) Field Observations- Probably the most essential of all monitoring programs as well as the most difficult to quantify into a database. Some of the more common field observations are :

- Noting the presence of waterfowl or other animal activity.
- Suspicious flows that might indicate either surface outbreak of an on-site septic system or break in a sewer line.
- Unusual growth of algae or other wetland plants that might indicate nutrient loading.

2. Optical Brightener Data Sheet (see Appendix A)

Measuring Water Flow with a Flowmeter

It is essential that all pertinent information be written on the Optical Brightener Data Sheet, at the time of placement, at the time of retrieval, and immediately after reading the results. Information as to total rainfall and the total number of days the sample was in place can be entered at a more convenient time if it is so desired. It should also be noted (because the O.B. pad remains on site for a period of time) that the total amount of rain that has fallen while the sample is in place is more appropriate than when the last rainfall occurred. For purposes of simplicity, it is sufficient to note total rainfall in one-half inch increments.

3. Proper handling

When handling samples that have been exposed to waters that might contain waste-water, it is always advisable to wear plastic or rubber gloves while handling these samples and to wash ones hands very thoroughly afterwards.

All rigid sampling devices should be rinsed thoroughly in a strong stream of tap water before reuse to prevent potential cross contamination.

It is also a good precaution to avoid *direct contact* with laundry soaps and detergents for 24 hrs. prior to handling any sampling equipment.

4. Quality Control

Although the analysis is relatively simple and straight forward, the reading of these samples should be done by people who have been trained in the reading of Optical Brightener results or at least involved in other forms of qualitative sampling.

As a quality control check, it is recommended that 10 to 20% of all O.B. pads be re-read by properly trained personnel. One source of obtaining this quality control check is the Gloucester Shellfish Department at (978) 281-9741

Another quality control check for monitoring groups is to have a designated portion of their retrieved samples quantitatively sampled. One source for obtaining quantitative results for a fee is:

Ozark Underground Laboratory
Rt. 1, Box 62
Protem, Mo.
417-785-4289

It should be noted that some laboratories require different protocol for the retrieving and handling of samples that will be tested for quantitative results. This information is best obtained by contacting the laboratory that will be conducting those tests.

B. Materials

1. Because Optical Brightener is so pervasive when dealing with cotton products, the first hurdle a would-be monitor must overcome is to find a reliable source of untreated cotton pads.

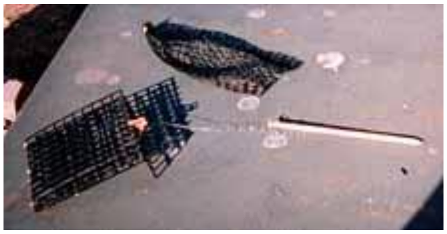
One source for purchasing untreated cotton pads is:

V.W.R. Scientific Products
200 Center Square Rd.
Bridgeport, New Jersey 08014
1-800-932-5000 Customer Service

Catalogue #21902-985

All cotton pads, regardless of their source, should be checked under a long wave Ultra Violet fluorescent light to make sure they do not contain Optical Brightener before they are used.

2. It is necessary to have a rigid sampling device that will hold the cotton pad securely in place while allowing water to easily pass through it.



Optical Brightener Sampling Devices

In open pipe or stream sampling it is recommended that the rigid sampling device be non-metal plastic or a vinyl coated black 1/2” wire cage that consists of two hinged pieces that measure approximately 5” by 5”. This cage should be fabricated so that it will rest at approximately a 30 to 45 degree angle. The open end of this cage is closed with an elastic band.

In sampling catch basins it is recommended that the sampling device be constructed from 1/2” mesh black plastic netting that is closed at the bottom to create a bag. Small stones are placed in the bottom of the bag so that it will not float. The cotton pad sampler is then stapled above these stones to the plastic netting.

One source for purchasing sampling devices is:

Winchester Fishing Co.
18 Washington St.
Gloucester, Mass. 01930
(978) 281-1619, 283-0757

3. A long wave 4-6 watt fluorescent Ultra Violet (U.V.) light should be used for analysis. Although the most costly component of O.B. sampling, this is critical as the U.V. light must be of sufficient strength and quality to make definitive results possible.

One source for purchasing a long wave U.V. 4-6 watt fluorescent light is:

V.W.R/Scientific Products
200 Center Square Rd.
Bridgeport, New Jersey 08014
1-800-932-5000

Step 2: Placement

Placing an Optical Brightener sampling device into a stream

Optical Brightener sampling is best suited for storm drains, pipes, and small streams. Avoid placement in larger bodies of water such as ponds, lakes, rivers, or estuaries, as the larger volume of water contained in these systems will likely dilute the concentration of Optical Brightener to such a degree that it can not be qualitatively detected.

In open pipe or stream sampling, the rigid vinyl coated sampling device is secured by an attached monofilament fishing line that is tied at the other end to either a branch, a rock, or an aluminum spike.

In sampling catch basins, the plastic net bag is lowered into the catch basin by use of monofilament fishing line that is tied several times to the top of the bag. The other end of this monofilament line is tied to a craft (popsicle) stick that is then wedged into the side of the grate cover. The monofilament line should be of sufficient length so that the bag will be suspended within the flow of water.

Properly placed rigid sampling devices are almost invisible to the casual passerby. Close attention must be paid to the exact location where they are placed or they may be difficult to retrieve.

Placing an Optical

The Optical Brightener sample is generally exposed for 7 days. This is done for a variety of reasons.

Brightener sampling device into a catch basin

Usually a volunteer(s) will have the same time off from one week to the next. This time frame also allows sufficient time for laundry to be done in the event one is monitoring a direct discharge from a single residence. If background interference hinders the sample from being read (eg. rust or sedimentation) then the length of time the sample is exposed can be shortened. If the result is repeatedly inconclusive (eg. retest) then the time exposed can be lengthened

Step 3: Retrieval

A. Pads are first rinsed in the sampling waters to remove as much sediment as is possible.

B. Then the samples are squeezed to remove as much water as is practicable without tearing or ripping the pad.

Retrieving and rinsing the exposed Optical Brightener pad ina stream

C. Next the exposed sampling pads are labeled or tagged for cross referencing.

Most tags and labels are made from white paper and contain Optical Brightener and can interfere with the reading of the sample. Labels cut from darker manila envelopes many times do *not* contain Optical Brightener. *All labels regardless of their source should be checked under the U.V. light to make sure they do not contain Optical Brightener before they are used* .

Labels should have information written on them as to location, day of placement, and day of removal. They are then stapled to the retrieved sampling pads and placed in a zip lock bag (to prevent cross contamination) and placed in a dark area.

D. After all the pads have been retrieved, cleaned, and labeled they are

Exposed Optical Brightener sampling pads drying on a monofilament line

dried out in a space where they will not come in contact with direct sunlight (preferably overnight) on a monofilament line. Cotton line can not be used as it contains Optical Brightener and can interfere with the reading of the sample.

The monofilament line should either be replaced or wiped clean before and after each drying with a damp non-exposed cotton sampling pad.

Step 4: The Analysis

A. The pads are placed on a table and viewed in a dark room under a long wave ultra violet fluorescent light. All lights are turned out, doors closed, and all measures possible are taken to prevent ambient light from entering the analysis room. The darker the room is, the easier it will be to read the results.

B. *A non-exposed sampling pad as well as a sampling pad that has been deliberately exposed to laundry effluent are used as controls and compared to each pad as it is exposed to the U.V. light* .

U.V. light and Optical Brightener sampling pads in the analysis room

C. There are three Qualitative Results: Positive, Retest, and Negative.

A pad will very definitely glow (fluoresce) if it is positive. If it is negative it will be noticeably drab and similar to the control pad. All other samples are undetermined or retests. As each pad is read it is placed in either the positive, negative, or retest pile.

D. In some instances only a portion of the pad or simply the outer edge will fluoresce after being exposed to Optical Brightener. This can be caused by many factors but is usually the result of an uneven exposure to the dye in the watercourse due to sedimentation or the way the pad was placed in the water.

In these cases, one can always account for the unevenness by associating the pattern with the sedimentation distribution, folds in the pad, etc. Regardless, as long as a portion of the pad fluoresces and one can explain why the remainder was not, it should be considered positive.

When in doubt, call it a retest.

There is never a borderline positive or a negative call.

Samples can be left in for a longer period of time and/or placed closer to a suspected source in order to get a more definitive result.

Three piles of Optical Brightener sample results with control pads

E. Since paper and cotton dust is so pervasive, it is common to see specks or spots of fluorescence on the sample or control pads. These should be ignored and not used to indicate a positive result.

F. After all the pads have been read, lights are turned back on and the labels read as to the sampling location.

Step 5: Data Interpretation

Optical Brightener results, especially when combined with other information can be an invaluable tool in identifying and locating sources of waste water pollution. The table in Appendix C, which is based on over 1,000 O.B. samples collected in Gloucester demonstrates the many ways this data can be utilized. Appendix B is a breakdown of all the results from those samples in Gloucester and is probably representative of what one might expect in a watershed based approach to a sampling program. The following are examples of case studies which demonstrate some of the different ways that Optical Brightener sampling has been used.

A. Storm Drain Cross-Connection

In Ipswich during routine storm drain monitoring, a sampling site repeatedly tested positive for Optical Brightener and yet parallel bacterial sampling indicated the site was relatively free from dry weather fecal coliform bacteria. When the upstream portion of this drainage system was subsequently sampled through use of Optical Brightener, a direct discharge from a washing machine was found connected into the storm drain. The homeowner had separated the laundry waste from his septic waste in an attempt to reduce flow to a very stressed septic system.

B. Sewage Exfiltration

In a nearby City, a local monitoring group found extremely high fecal coliform levels in a storm drain that discharged into the harbor. Since the City was totally sewered, it was first thought that the source of bacteria must be non-human in origin. Optical Brightener sampling was then conducted at this site and results were consistently positive. After tracing the Optical Brightener through the street drain system, the group located the source of the problem, a leaky sewer pipe. Similar work done within this City identified several similar cases of sewer system exfiltration and even entire City streets in the older sections of town which were never tied into the central sewer system.

C. Human/Animal Waste Differentiation

In 1996 voluntary sampling was conducted in Gloucester prior to the seasonal opening of a conditionally approved shellfishing area.

- During dry weather, sampling was conducted at the discharge point of a perennial feeder stream. Volume measurements were taken and while Optical Brightener results were negative, fecal coliform results were unacceptably high.
- This site was again sampled in dry weather as was an additional site located further upstream.
- Fecal coliform results for the discharge point were once again unacceptably high and Optical Brightener results once again were negative.
- While volume measurements and Optical Brightener results for the upstream site mirrored those taken at the discharge point, fecal coliform results were significantly lower.
- Bacterial loading was then calculated for the discharge point and converted into human equivalents. Bacterial loading sometimes is expressed as human equivalents (H.E.). One H.E. is the amount of fecal coliform produced by an adult human in one day, or two billion fecal coliforms per day. The H.E. calculated at the discharge point was 11.75 people per day.
- It was known from previous experience (as well as volume measurements) that there was no other inflow to this stream between the two sampling sites. From past experience it was also known that this section of the stream is fairly urbanized and was bordered by only four houses.
- Negative Optical Brightener results and knowledge of the surrounding watershed suggested that it was unlikely this amount of bacterial loading was human in origin. Based on the negative Optical Brightener results, the dry weather bacterial loading, and previous watershed knowledge it was predicted that the likely source for the unacceptably high fecal coliform results was probably non-human in source. Because of the urbanized nature of the stream and the limited number of warm blooded species that could be expected to reside there, it was further predicted that the non-human source was very likely

to be waterfowl. Whatever the source, it still needed to be pinpointed and remediated.

- The stream was then walked and sampled by the two Local Shellfish Constables. Midway up the stream between the two sampling sites they found several waterfowl penned in the middle of the stream. Fecal coliform results taken above the pen were low and fecal coliform results taken below the pen were very high. The source had been “boxed in".
- The Local Health Department was contacted and a Health Agent spoke to the residents of the property. The problem was explained to them in detail and they agreed to remove the pen from the stream.
- Subsequent sampling confirmed that the penned waterfowl were the cause of the unacceptably high fecal coliform results and the shellfishing area was opened on schedule.

Conclusions

A. Simple, low cost but labor intensive "detective" work

Drainage from a perimeter drain to a catch basin

- In its simplest form the Optical Brightener sampler is merely dye testing. At the "business end of the pipe" people generally are obliging enough to place dye into their domestic waste water. It is only logical that nearby streams, wetlands, and storm drains be sampled to see if it is detectable from the other end.

- Although an effective Optical Brightener sampling program is *very* labor intensive, the cost of materials is only about $450.00. Most of that expense is for a good 4-6 watt long wave U.V. fluorescent light. With extra bulbs this should cost about $240.00.

- It has been our experience that a two person team can comfortably do 12 - 15 Optical Brightener samples per day. Any more samples than that and one runs the risk of having a trade-off between quantity of samples with quality of results.

- Optical Brightener sampling is very labor intensive because of: 1.) the paperwork, 2.) care and cleaning of various sampling devices and 3.) because the O.B. pad remains on site for a period of time, a person must travel twice to the same sampling location (placement and retrieval).

B. Optical Brightener results alone are not suitable for enforcement action but when done in combination with a larger sampling program is an invaluable indicator in helping to identify:

- faulty septic systems
- sewage exfiltration
- storm drain cross-connections
- human/animal waste differentiation < e --

Placing an Optical Brightener sampling device at a suspected septic system break out through a retaining wall