Proposal to Repeat a Groundwater Tracer Test at Malad Gorge Springs

By Neal Farmer IDWR

<u>Background and Objective:</u>

A Fluorescein test was started on April 7th provided the spatial distribution for the presence and concentration of dye from charcoal packets deployed for one week as well as the azimuth of flow direction. The charcoal packets continuously absorb dye as it flows by in the spring water building concentrations in the charcoal as more time elapses even if the water concentration actually decreases. At 3.5 days after the release of the dye into the Malad Gorge picnic area well the pump was turned on and tested for presence of dye which none was detected and indicates all of the dye flowed out of the well towards the springs in a short period of time. At 7 days after release of the dye it was only detected in one spring location (MG–7) at 0.012 parts per billion (ppb) and samples collected later showed no detection at all in any of the samples sites also indicating that nearly all of the dye passed out of the aquifer in one weeks time frame.

The charcoal packet data will not provide an adequate time of travel for calculating the groundwater velocity thus a second test is proposed to release Rhodamine WT dye under the same conditions as the previous test to define the groundwater flow velocity. An in-situ fluorometer with a data logger will be deployed at site MG-7 prior to dye release and programmed to collect a water concentration every hour for a week. This will provide a concentration verse time breakthrough curve that allows for determination of dye travel time for first arrival and peak concentration which is used to determine groundwater flow velocity.

Rhodamine WT is certified by ANSI/NSF for Standard 60 potable water and approved by the EPA as noted by a copy of the certification located in the appendix for use in surface water streams up to 100 ppb where there is no public drinking water intakes up to 100 ppb. There are no public drinking water intakes in the Malad Gorge River or in the Snake River in this general area. The test will be designed with the goal of a maximum Rhodamine WT resurgent concentration of 100 ppb.

The type of tracer selected for a tracer test is dependent on many factors. One such factor includes the purpose of the study. For example, if information such as the velocity of the ground water, porosity, and the dispersion coefficient are of interest, then a conservative tracer should be used. Other factors include type of medium, available funds, the stability of the tracer, detectability of tracer, difficulty of sampling and analysis (availability of tracer, ease of sampling and availability of technology for analysis), physical/chemical/biological properties of tracer and public health considerations (Davis et. al., 1985). Various components go into the design of a tracer test. For the previous tracer test, the following elements were considered and evaluated: the conceptual design, down gradient receptors such as humans, aquaculture industry and endangered species, transient hydrologic barriers such as canal recharge, selection of initial mass of tracer or its concentration, observation wells, sampling schedule and locations, and monitoring.

FLUOROMETRIC FACTS

Bulletin No. 104 Fluorescent Tracer Dyes

Rhodamine WT has been approved as a tracer dye in potable water in the United States (1).

Rhodamine WT is related to rhodamine B, a tracer in common use in the 1960s. It was developed to overcome a disadvantage of rhodamine B, absorption on suspended sediment. The same modification was expected to reduce toxicity, and limited testing bore this out.

Rhodamine WT was an immediate success as a tracer in marine systems and in wastewater. While it was also used in potable water, such use was occasionally forbidden on the grounds that it did not have formal Federal approval for such use. Rhodamine WT is now approved for such use. A brief history follows.

While the EPA has sole responsibility for identifying those substances which may be used a tracers (2), the Food and Drug Administration (FDA) does issue policy statements. The FDA did issue such a policy statement on 22 April 1966 concerning rhodamine B (3). A temporary tolerance limit for ingestion of rhodamine B was set at 0.75 mg per day. Based on normally expensed water consumption, the tolerance would not be exceeded unless the concentration approaches 370 parts per billion (PPB). Noting that 30 PPB may be detected visually in a glass of water, and 10 PPB is visible in larger volume such as a clear reservoir, the FDA pointed out that if the dye is not visible, the tolerance would not be exceeded. The USGS, a large user of fluorescent dye tracers, directed that the concentration should not exceed 10 PPB at the intake of a water supply (4). The visual and instrumental detectability of rhodamine WT, based on active ingredient, is about the same as rhodamine B (rhodamine WT is supplied as a 20% aqueous solution).

Ten parts per billion may not sound like much to the uninitiated, but it is a thousand times the limit of detectability guaranteed by Turner Designs on its Model 10 Series Fluorometers (5). Background fluorescence caused by fluorescent materials in the water being studied usually limits detectability. But even so, measurements can be made to 0.1 part per billion of rhodamine WT (active ingredient), in raw sewage!

On April 10, 1980, Dr. Joseph A. Cotruvo of the U.S. EPA issued a memo stating that the EPA considers rhodamine WT to be equivalent to rhodamine B (1). More recently, the following policy letter was sent to Crompton and Knowles:

United States Environmental Protection Agency
Washington, D.C. 20460

Aug 2 1988

Office of Water Ms. Janice Warnquist Chemical Safety Manager
Crompton and Knowles Corporation

P.O. Box 341 (500 Pear Street)
Reading, Pennsylvania 19603

Dear Ms. Warnquist:

The Criteria and Standards Division (Office of Drinking Water) has reviewed the available data on chemistry and toxicity of Rhodamine dyes. We would not anticipate any adverse health effects resulting from the use of Rhodamine WT as a fluorescent tracer in water flow studies when used with the following guidelines.

-A maximum concentration of 100 micrograms/liter Rhodamine WT is recommended for addition to raw water in hydrological studies involving surface and ground waters.

-Dye concentration should be limited to 10 micrograms/liter in raw water when used as a tracer in or around drinking water intakes.

-Concentration in drinking water should not exceed 0.1 micrograms/liter. Studies which result in actual human exposure to the dye via drinking water must be brief and infrequent. This level is not acceptable for chronic human exposure.

-In all of the above cases, the actual concentration used should not exceed the amount required for reasonably certain detection of the dye as required to accomplish the intended purpose of the study.

The Criteria and Standards Division recommends that Rhodamine B not be used as a tracer dye in water flow studies.

This advisory supersedes all earlier advisories issued by EPA on the use of fluorescent dyes as tracers in water flow studies. This advisory is granted on a temporary basis only.

EPA is terminating its voluntary additives advisory program as announced in the Federal Register (53 FR, 25586, July 7, 1988). A copy of the Federal Register Notice is enclosed for your convenience. All EPA advisory opinions issued within the framework of the additives program will expire on April 7, 1990.

Our opinion concerning the safety of this tracer dye does not constitute an endorsement, nor does it relate to its effectiveness for the intended use. If this letter is to be used in any way, we require it to be quoted in its entirety.

Sincerely,

Arthur H. Perler, Chief Science
and Technology Branch Criteria
and Standards Division

Enclosure

REFERENCES

1. Cotruvo, J. A., RHODAMINE WT AND B, Memo to P. J. Traina, dated April 10, 1980

2. Letter from A. D. Laumback, FDA, to George Turner, dated 7 June 1977

3. POLICY STATEMENT ON USE OF RHODAMINE B DYE AS A TRACER IN WATER FLOW STUDIES, Department of Health, Education and Welfare, dated 22 April 1966

4. Kilpatrick, F. A., DOSAGE REQUIREMENTS FOR SLUG INJECTIONS OF RHODAMINE BA AND WT DYES, U. S. Geological Survey, Prof. Pater 700-B, B250-253 (1970)

5. FIELD FLUOROMETRY, Monograph available at no charge from Turner Designs

TURNER DESIGNS
845 W.Maude Ave. Sunnyvale, CA 94085 www.turnerdesigns.com
Telephone 408-749-0994 Toll Free 877-316-8049 Fax 408-749-0998

TO PLACE AN ORDER OR FOR TECHNICAL ASSISTANCE CONTACT US AT:

1-800-394-0678

Kingscote Chemicals · 3334 S. Tech Boulevard · Miamisburg, Ohio 45342
Phone (937) 886-9100 · Fax (937) 886-9300
E-mail: sales@brightdyes.com · www.brightdyes.com

CERTIFIED TO MEET EPA STANDARDS

BRIGHT DYES

This is a Certification that these products conform to the ANSI/NSF Standard 60 for potable water as set forth by the EPA in The Clean Water Act.

NSF

* Official Listing as Certified by NSF detailed on back of certification

Location and Site Conditions

The legal location is Township 6S Range 13E, section 36 in Gooding County. Use of Rhodamine WT as a tracer is appropriate for this type of geology that exhibits fracture and conduit flow characteristics with high flow velocities and no sediments. The well targeted for dye release at Malad Gorge State Park is located in the ‘Park Picnic Area’ as shown (central lower right side) in Figure 2 with a green circle. As before, the pump will be turned off for 3 days after dye release. Eleven sample locations in the gorge are shown with the labels MG # at points of spring discharge and a down stream sample station at the Idaho Power Diversion. Figure 1 also shows the locations and integrated concentrations from charcoal packets from the previous Fluorescein dye test with MG 7 receiving the highest concentration and therefore the greatest hydraulic connection to the well. A ‘SCUFA’ in-situ fluorometer will be deployed at site MG 7 for the second test. Since it is now know how the local flow system works the amount of dye can be reduced significantly.

Figure 1. The location of Malad Gorge and park picnic area with the well noted in the lower right. Sample locations are noted as MG # with Fluorescein integrated concentrations in ppb units from charcoal packets.

Geologic Conditions and Subsurface Conceptual Flow Model

Water flows along the path of least resistance (high hydraulic conductivity) and the highest flows are expected to be through basalt contact zones with possible ‘conduit’ type of flow path characteristics. In tandem but at a slower rate, water will also flow both vertically and horizontally through fractures in the massive portion of the basalt from the overlying flow contact zone and diffuse into the low permeability pore spaces. Approximate horizontal groundwater flow velocities may be inferred from dye tracer tests by Farmer (2001) and Dallas (2005) in a basalt flow 200 feet in elevation beneath the Bell Rapids Irrigation District in Twin Falls County.

The well drilling report shows open hole (10 inch diameter?) with no casing below 21 feet and there is broken basalt within the saturated zone of the aquifer (Figure 2). Water level in the well on March 20, 2009 was 191.76 feet below land surface but the dye will be released into the upper level of the broken basalt at 212 feet below land surface. Figure 3 shows the conceptual 2-D model for conditions and dye transport to the springs and river. It is about 1,000 feet between the well and the nearest springs. There are no wells between the Park well and the springs in the gorge.

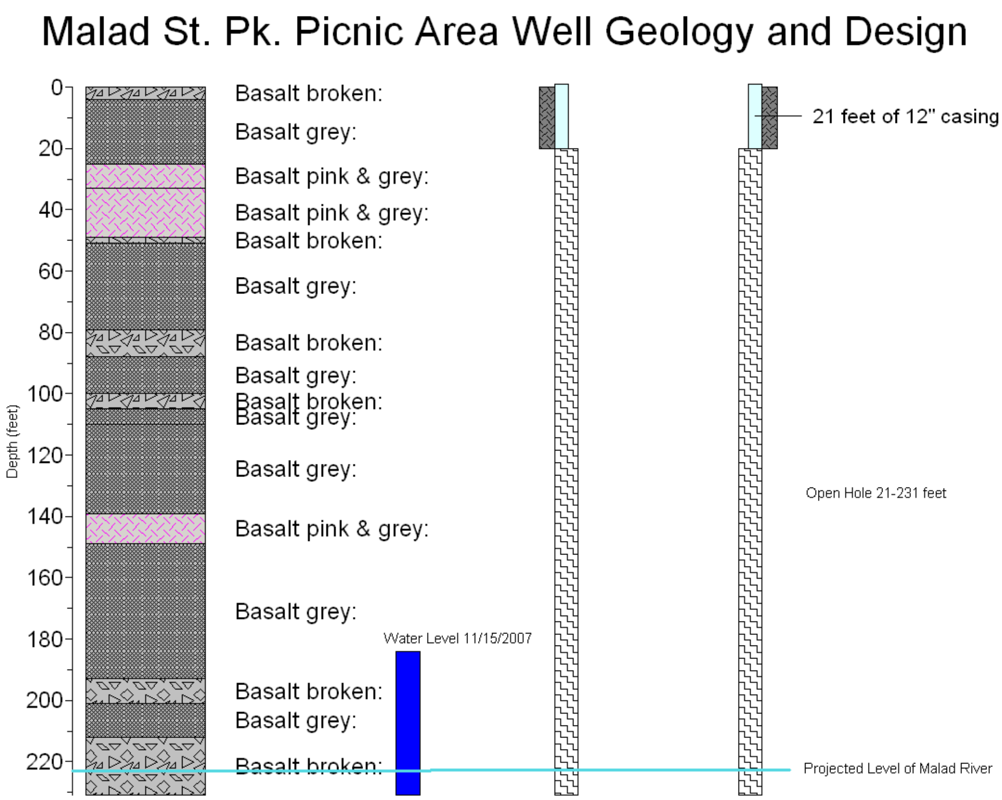

Figure 2. Geology and well construction for the Malad Gorge Park picnic area well.

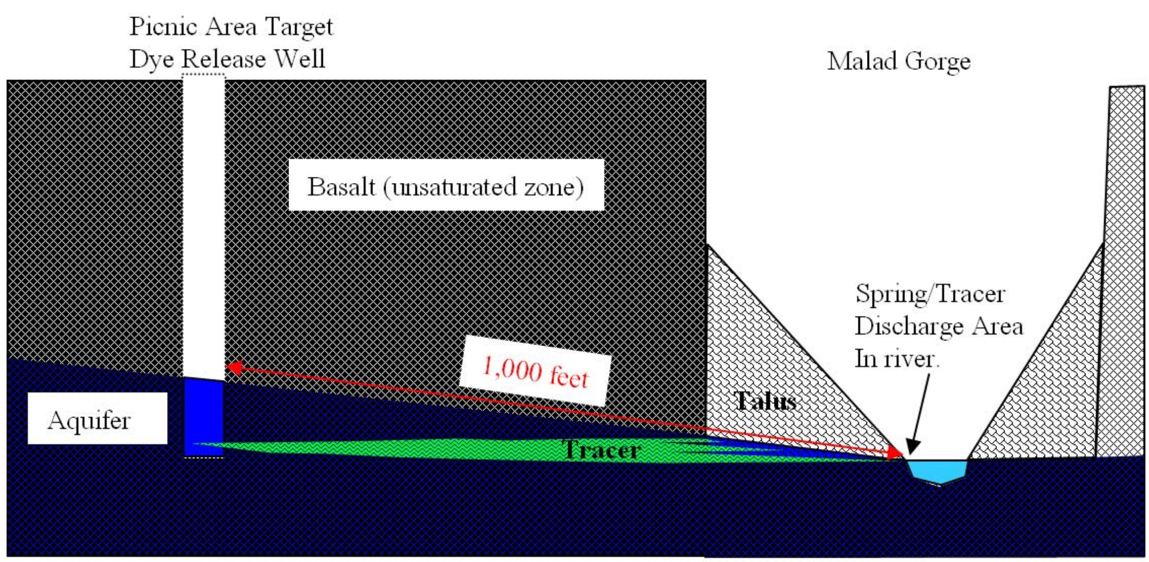

Figure 3. Conceptual 2-D cross section model of the tracer test at Malad Gorge.

Proposed Approach to Trace Fluorescein Dye at Malad Gorge State Park

The same approach will be used for this test as for the Fluorescein test started on April 7, 2009. The previous test data, a USGS field and lab procedural report by James Wilson (1986), a thesis by Dallas (2005) and recommendations by The Ozark Underground Laboratory Handbook by Tom Aley, along with personal experience will be used as guidance for detailed project implementation.

1. **Sample site MG 7 is selected** for in-situ real time instantaneous sampling in the gorge and the well will be sample as well by collecting water samples before and after the test.

2. **Sample frequency** at MG 7 will be every hour with 50 mL of pretest water samples collected.

3. **Release 2 gallons of liquid Rhodamine WT** (5% concentration active ingredient) directly into well water through plastic tubing at the 212 foot depth level. The amount of dye is based on literature review and past tracer tests performed within a basalt aquifer as noted in the appendix documents (Dallas 2005; Farmer and Larson, 2001;
   - Thomas Aley states on page 13 of the 2002 Tracer Handbook "*There is no credible standard equation for estimating dye quantities needed for groundwater tracing work.*" and on page 14 "*We seldom use less than one pound of any of the dyes for any particular dye introduction. In Karst areas, most dye introductions use one to five pounds of the selected dye except where the dye is introduced into wells, borings, or backhoe pits. When dye introductions are made into these man-made locations, dye quantities are most commonly in the range of five to ten pounds for Fluorescein or eosine and ten to twenty pounds of rhodamine WT. Groundwater tracing in non-karst areas typically requires two or three times more dye than in karst areas.*"

   The test is designed to attain a maximum resurgent dye concentration of 100 ppb which is allowed by the EPA as shown earlier in this document under "Fluorometric Facts". Once the dye enters the river it is anticipated it will be below detection limits of the instruments. After the test is over the well will be tested for bacteria by Malad Gorge State Park staff and can be disinfected if necessary. Bacteria were absent in the well water after the last test was completed based on lab analysis.

4. **Analyze water samples** collected from the well and site MG 7 in the lab by IDWR staff 'in-house' method with a calibrated lab fluorometer model TD-700 made by Turner Designs. All water samples will be retained and stored in a refrigerator until the test is completed.

5. **QA/QC** will be attained by calibrating both field and lab instruments with standards according to the manufactures guidelines and USGS protocol (Wilson et al, 1986).

6. **Date analysis and report writing** will be performed at the end of the test discussing and describing the results and recommendations for future actions. Copies will be made available.

Biological Considerations

Rhodamine WT has very low toxicity, biologically degrades and photo degrades when exposed to ultraviolet light. A literature search (see appendix) has been made to ensure that biological risks to humans (Field et al, 1995, Smart 1984), human food sources, and aquatic species such as fish, snails and Daphnia are taken into consideration for the test design and there is no known adverse effects anticipated given the project design. Dye tracing has been performed at locations with endangered species (snails and shellfish), human food sources (trout farms), and salmon spawning beds for over half a century with the approval of the U.S. Fish and Wildlife Service, state agencies and other private and non-profit organizations (Aley, 2008).

Human

Human health and safety are addressed in partial from the MSDS sheets provided in the appendices. The dye is EPA certified to conform to the ANSI/NSF Standard 60 for use in potable public water supplies as set forth by the Clean Water Act (see a copy of the certification in the appendices) and maximum concentrations in surface water at 100 ppb. EPA (1995) states clearly that Rhodamine WT should not exceed 1,000 – 2,000 ppb at the point of groundwater discharge and it would not present an acute toxic threat at or substantially above the recommended 2,000 ppb concentration. Smart (1984) states "Persistent dye concentrations in tracer studies should not cause problems provided they are below 100 ppb". After the test, the pump will be turned on and the system flushed until the water is colorless. The water will be tested for residual dye and continued flushing until levels drop to 0.1 ppb. The resurgent concentrations from the springs and in the river will not be a risk to humans since there is no consumption of this water by humans.

Snails

Endangered and non-endangered snails were considered by seeking professional recommendations and information. Tom Aley has performed numerous dye tracer tests at locations where endangered snails are present with the blessing of the U.S. Fish and Wildlife Service (Aley, 2008). A literature search was performed and numerous snail experts contacted about the potential risk. The USGS in 1973 conducted a study which exposed oyster eggs and larvae to Rhodamine WT with no abnormal growth observed. The MSDS documents "no developmental abnormalities or toxicity to oyster larvae at 100,000 ppb" which is an extremely high concentration. Dr. John Stark, who is the director and a professor at Washington State University, stated in regards to snails that Fluorescein should not pose a problem to snails if the concentration is below 300.0 ppm. Rhodamine is in the same family of dyes with similar characteristics. John Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species (see Daphnia section below).

Fish

Two potential issues, native or indigenous populations and commercial production are addressed in regards to fish. The MSDS documents that the LC50 for Rainbow Trout at 96 hours of 320,000 ppb which is an extremely high concentration. Dye tracing has been approved by federal regulatory agencies (EPA, 1995) and performed in streams and rivers for over half a century at locations that include sensitive environments and endangered species such as in Salmon spawning beds with no problems or issues (Aley, 2008). A USGS study in 1973 exposed trout and salmon smolts to Rhodamine WT at a concentration of 10,000 ppb for 17.5 hours then increased the concentration to 375,000 for an additional 3.5 hours with no ill effects to the trout or salmon. The fish remained healthy in dye free water a month after the test was completed. Resurgent dye concentrations are expected to be very low ranging from 0.1-100 ppb from the springs and diluted after mixing with additional river water near the spring area above the upper IPCo. diversion structure. Even more dilution will occur downstream from more spring discharge into the river where it is anticipated concentrations of dye will be at or below the minimum detection limits. The endemic species of Shoshone Sculpin are present in the lower Malad River below the Highway 30 Bridge (Bowler, 1992 and personal communication with Malad Gorge staff, 2008). The dye is expected to be below detection limits by the time it flows through this section from the effects of dilution, biological degradation, ultraviolet light degradation, and absorption onto concrete and rock substrate.

Daphnia

Daphnia are small, planktonic crustaceans, between .2 and 5 mm in length (Figure 5). *Daphnia* are members of the order Cladocera, and are one of the several small aquatic crustaceans commonly called water fleas because of their saltatory swimming style (although fleas are insects and thus only very distantly related). They live in various aquatic environments ranging from acidic swamps to freshwater lakes, ponds, streams and rivers (Wikipedia, 2008).

Figure 5. Photo of Daphnia crustacean (Wikipedia, 2008).

The MSDS documents the LC50 for Daphnia Magna at 170,000 ppb which is an extremely high concentration. Dr. John Stark was contacted by IDWR staff (personal communication) and discussed the risk of Fluorescein dye to both snails and Daphnia. Although this test will use Rhodamine WT, it is still in the same family of dyes with similar low risk factors and therefore useful to compare. Dr. Stark is an ecotoxicologist who specializes in ecological risk assessment of threatened and endangered species. He runs the WSU Salmon toxicology research laboratory and has recently started work on the effects of pesticides on endangered butterfly species. Stark is also a population modeler and has developed population-level risk assessments based on matrix models and differential equation models.

John D. Stark
Director, WSU Puyallup Research & Extension Center
and Professor, Ecotoxicology Program
7612 Pioneer Way
Puyallup, WA 98371-4998

http://entomology.wsu.edu/Profiles/stark.html

Phone: (253) 445-4519
E-Mail: starkj@wsu.edu

Dr. Stark provided a professional paper (Walthall and Stark, 1999) that addresses the risk of dyes to Daphnia and the research paper concluded there is little or no issues with Fluorescein dye concentrations below 337 (278±403) mg/liter (ppm) and the resurgent dye concentration is expected to be several orders of magnitude less in concentration within the range of 0.1-100 ppb.

Appendix of Information Used for Proposed Implementation

1. Certification of Approval for use in Potable Water & Safety Reference
2. Material Safety Data Sheet for Rhodamine WT
3. Flourometric Facts Bulletin – Rhodamine WT
4. Technical Data Bulletin
5. USGS Report (title page only) “Fluorometric Procedures for Dye Tracing”
6. Groundwater Tracing Handbook by Thomas Aley
7. Reference: Groundwater Tracer Tests at Hagerman Fossil Beds N.M. 2001
8. Reference: Hydrologic Study of the Deer Gulch Basalt 2005
9. Reference: Tracer Tests in Columbia River Basalts 1998
10. Resume of Thomas Aley – author of Groundwater Tracing Handbook by Ozark Underground Laboratory.
11. List of References
12. USGS Rhodamine WT Reader Information Sources

The NSS Bulletin - **ISSN 1090-6924**
Volume 46 Number 2: 21-33 - October 1984
A publication of the National Speleological Society

A Review of the Toxicity of Twelve Fluorescent Dyes Used for Water Tracing

P.L. Smart

Abstract

Toxicological information is reviewed for twelve fluorescent dyes used in water tracing, Fluorescent Brightener 28, Tinopal CBS-X, Amino G Acid, Diphenyl Brilliant Flavine 7GFF, Pyranine, Lissamine Yellow FF, Fluorescein, Eosine, Rhodamine WT, Rhodamine B, Sulphorhodamine B and Sulphorhodamine G. Mammalian tests indicate a low level of both acute and chronic toxicity. **However, only three tracers could be demonstrated not to provide a carcinogenic or mutagenic hazard**. These were Tinopal CBS-X, **Fluorescein** and **Rhodamine WT**. Rhodamine B is a known carcinogen and should not be used. In aquatic ecosystems, larval stages of shellfish and algae were the most sensitive. Persistent dye concentractions in tracer studies should not cause problems provided they are below 100 µg/l.

http://www.caves.org/pub/journal/PDF/V46/v46n2-Smart.htm

PREVENTATIVE MEASURES

PERSONAL PROTECTIVE EQUIPMENT

GLOVES	RUBBER
RESPIRATORY	NONE REQUIRED UNDER NORMAL CONDITIONS
EYE PROTECTION	GOGGLES
CLOTHING	PROTECTIVE CLOTHING SHOULD BE WORN WHERE CONTACT IS UNAVOIDABLE.
OTHER	HAVE ACCESS TO EMERGENCY EYEWASH.
ENGINEERING CONTROLS	NOT NECESSARY UNDER NORMAL CONDITIONS USE LOCAL VENTILATION IF DUSTY CONDITIONS EXIST.
SPILL OR LEAK RESPONSE	CONTAIN AND CLEAN UP SPILL IMMEDIATELY, PREVENT FROM ENTERING FLOOR DRAINS. SWEEP POWDERS AND PLACE IN WASTE DISPOSAL CONTAINER, FLUSH AFFECTED AREA WITH WATER.
WASTE DISPOSAL	INCINERATE OR REMOVE TO A SUITABLE SOLID WASTE DISPOSAL SITE, DISPOSE OF ALL WASTES IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REGULATIONS.
HANDELING PROCEDURES AND EQUIPMENT	NO SPECIAL REQUIREMENTS.
STORAGE REQUIREMENTS	STORE AT ROOM TEMPERATURE BUT ABOVE THE FREEZING POINT OF WATER
SHIPPING INFORMATION	KEEP FROM FREEZING

FIRST AID MEASURES

FIRST AID EMERGENGY PROCEDURES

EYE CONTACT	FLUSH EYES WITH WATER FOR AT LEAST 15 MINUTES. GET MEDICAL ATTENTION IF IRRITATION PERSISTS.
SKIN CONTACT	WASH SKIN THOROUGHLY WITH SOAP AND WATER. GET MEDICAL ATTENTION IF IRRITATION DEVELOPS.
INHALATION	IF DUST IS INHALED, MOVE TO FRESH AIR. IF BREATHING IS DIFFICULT GIVE OXYGEN AND GET IMMEDIATE MEDICAL ATTENTION.
INGESTION	DRINK PLENTY OF WATER AND INDUCE VOMITING. GET MEDICAL ATTENTION IF LARGE QUANTITIES WERE INGESTED OR IF NAUSEA OCCURS. NEVER GIVE FLUIDS OR INDUCE VOMITING IF THE PERSON IS UNCONSCIOUS OR HAS CONVULSIONS.

SPECIAL NOTICE

END OF MATERIAL SAFETY DATA SHEET

MSDS PREPARATION INFORMATION

PREPARED BY:	T. P. MULDOON (937) 886-9100
DATE PREPARED:	1/1/08

PRODUCT INFORMATION

MAUNFACTURED BY:	KINGSCOTE CHEMICALS 3334 S. TECH BLVD. MIAMISBURG, OHIO 45342
CHEMICAL NAME	NOT APPLICABLE
CHEMICAL FORMULA	NOT APPLICABLE
CHEMICAL FAMILY	XANTHENE DYE FORM

HAZARDOUS INGREDIENTS

DESCRIPTION	%	T.L.V.	C.A.S. #
TRIMELLITIC ACID	3.0	NONE	528-44-9

	LD/50, SPECIES	LC/50, SPECIES
ORAL (MOUSE)	2500 MG/KG	NONE AVAILABLE
DERMAL (RABBIT)	NOT AVAILABLE	NOT AVAILABLE

PHYSICAL DATA

PHYSICAL STATE	LIQUID
ODOR AND APPEARANCE	DARK RED LIQUID WITH MILD ODOR
SPECIFIC GRAVITY	~1.15
VAPOR DENSITY (mm Hg @ 25 ° C)	NOT APPLICABLE
VAPOR DENSITY (AIR =1)	NOT APPLICABLE
EVAPORATION RATE (Butyl Acetate = 1)	NOT APPLICABLE
BOILING POINT	~ 100 degrees. C (212 degrees. F)
FREEZING POINT	~ 10 degrees C (14 degrees F)
pH	10.4 TO 10.8
SOLUBILITY IN WATER	VERY SOLUBLE

FIRE HAZARD

CONDITION OF FLAMMABILITY	NON-FLAMABLE
MEANS OF EXTINCTION	WATER FOG, CARBON DIOXIDE, DRY CHEMICAL, WEAR SCBA
FLASH POINT AND METHOD	NOT APPLICABLE
UPPER FLAMABLE LIMIT	NOT APPLICABLE
LOWER FLAMABLE LIMIT	NOT APPLICABLE
AUTO-IGNITION TEMPERATURE	NOT APPLICABLE
HAZARDOUS COMBUSTION PRODUCTS	BURNING MAY PRODUCE OXIDES OF CARBON & NITROGEN
UNUSUAL FIRE HAZARD	NOT APPLICABLE

EXPLOSION HAZARD

SENSITIVITY TO STATIC DISCHARGE	NOT APPLICABLE
SENSITIVITY TO MECHANICAL IMPACT	NOT APPLICABLE

REACTIVITY DATA

PRODUCT STABILITY	STABLE
PRODUCT INCOMPATIBILITY	DO NOT MIX WITH ACIDS
CONDITIONS OF REACTIVITY	NOT APPLICABLE
HAZARDOUS DECOMPOSITION PRODUCTS	SEE HAZARDOUS COMBUSTION PRODUCTS

TOXICOLOGICAL PROPERTIES

SYMPTOMS OF OVER EXPOSURE FOR EACH POTENTIAL ROUTE OF ENTRY:

INHALLATION, ACUTE	TRIMELLITIC ACID MAY CAUSE IRRITATION
INHALATION, CHRONIC	NOT KNOWN
SKIN CONTACT	MAY BE IRRITATING TO THE SKIN. WILL CAUSE TEMPORARY STAINING OF THE SKIN ON CONTACT.
EYE CONTACT	MAY CAUSE IRRITATION
INGESTION	URINE MAY BE A RED COLOR UNTIL THE DYE HAS BEEN WASHED THROUGH THE SYSTEM.
EFFECTS OF ACUTE EXPOSURE	DIRECT CONTACT MAY CAUSE IRRITATION TO THE EYES, SKIN, AND RESPIRATORY TRACT.
EFFECTS OF CHRONIC EXPOSURE	NOT KNOWN
THRESHOLD OF LIMIT VALUE	NOT APPLICABLE
CARCINOGENICITY	NOT LISTED AS A KINOWN OR SUSPECTED CARCINOGEN BY IARC, NTP OR OSHA.
TERATOGENICITY	NONE KNOWN
MUTAGENICITY	CONFLICTING EVIDENCE AS TO MUTAGENICITY OF THE DYE CONTAINED IN THIS PRODUCT.
TOXICOLOGY SYNERGISTIC PRODUCTS	NONE KNOWN

REGULATORY INFORMATION

SARA SECTION 303:	NONE FOUND
SARA (311, 312) HAZARD CLASS:	IMMEDIATE HEALTH HAZARD
SARA (313) REPORTABLE CHEMICAL (%):	NONE
METAL CONTENT:	THIS PRODUCT IS NOT A METALLIZED DYE
TSCS INVENTORY STATUS	ALL COMPONENTS ARE INCLUDED ON TSCA SECTION 8
CALIFORNIA PROPOSITION 65 CHEMICALS:	NONE
TSCA SECTION 12 (B) EXPORT REGULATIONS:	NOT SUBJECT TO TSCA 12 (b) EXPORT REGULATION

ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION:	LC50: >320 mg/L RAINBOW TROUT (96 Hour) LC50: 170 mg/L DAPHINA MAGNA

NO DEVELOPMENTAL ABNORMALITIES OR TOXICITY TO OYSTER LARVAE AT 100 mg/L

BRIGHT DYES

Division of Kingscote Chemicals ®

WATER TRACING DYE

FWT RED PRODUCTS

TECHNICAL DATA BULLETIN

Bright Dyes FWT Red products are specially formulated versions of Rhodamine WT dye for convenient use in water tracing and leak detection studies. This bright, fluorescent red dye is certified by NSF International to ANSI/NSF Standard 60 for use in drinking water. It may be detected visually, by ultraviolet light and by appropriate fluoremetric equipment. Today it is most often used visually. Visually the dye appears bright pink to red, depending on its concentration and under ultraviolet light as bright orange.

The dye is resistant to absorption on most suspended matter in fresh and salt water. However, compared to Bright Dyes FLT Yellow/Green products it is significantly more resistant to degradation by sunlight and when used in fluoremetry, stands out much more clearly against background fluorescence. As always the suitability of these products for any specific application should be evaluated by a qualified hydrologist or other industry professional.

General Properties	**Tablets**	**Liquids (200)**	**Powders**
Detectability of active ingredient [1]	Visual <100 ppb	Visual <100 ppb	Visual <100 ppb
Maximum absorbance wavelength [2]	550/588 nm	550/588 nm	550/588 nm
Appearance	Dark red convex 1.6cm diameter	Clear dark red aqueous solution	Dark red fine powder
NSF (Max use level in potable water)	0.3 ppb	0.8 ppb	0.1 ppb
Weight	1.05 gms ± 0.05		
Dissolution Time [3]	50% < 3 minutes 95% < 6 minutes		50% < 3 minutes 95% < 6 minutes
Specific Gravity		1.15 ± 0.05 @ 25° C	
Viscosity [4]		4.3 cps	
pH		10.6 ± 0.20 @ 25° C	

Coverage of Products	**One Tablet**	**One Pint Liquid**	**One Pound Powder**
Light Visual	604 gallons	250,000 gallons	467,000 gallons
Strong Visual	60 gallons	25,000 gallons	46,700 gallons

Caution: These products may cause irritation and/or staining if allowed to come in contact wit the skin. The use of gloves and goggles is recommended when handling this product, as with any other dye or chemical.

To our best knowledge the information and recommendations contained herein are accurate and reliable. However, this information and our recommendations are furnished without warranty, representation, inducement, or license of any kind, including, but not limited to the implied warranties and fitness for a particular use or purpose. Customers are encouraged to conduct their own tests and to read the material safety data sheet carefully before using.

[1] In deionized water in 100 ml flask. Actual detectability and coverage in the field will vary with specific water conditions.

[2] No significant change in fluorescence between 6 and 11 pH.

[3] (One tablet, 1 gram of powder), in flowing deionized water in a 10 gallon tank.

[4] Measured on a Brookfield viscometer, Model LV, UL adapter, 60 rpm @ 25° C.

Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter A12

FLUOROMETRIC PROCEDURES FOR DYE TRACING

By James F. Wilson, Jr., Ernest D. Cobb, and Frederick A. Kilpatrick

BOOK 3

APPLICATIONS OF HYDRAULICS

Revised 1986

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The Ozark Underground Laboratory's

GROUNDWATER TRACING HANDBOOK

A handbook prepared for the use of clients and colleagues of the Ozark Underground Laboratory 2002

Thomas Aley

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Hagerman Fossil Beds National Monument

Neal Farmer[1] and Isaac Larsen[2]

Technical Report

January 2001

[1]Ground Water Geologist, U.S. Department of the Interior, National Park Service, Hagerman Fossil Beds National Monument, Hagerman, Idaho.

[2]Geology Student, Department of Geology, Carleton College.

United States Department of the Interior
National Park Service

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FOSSIL BEDS NATIONAL MONUMENT, IDAHO

A Thesis
Presented in Partial Fulfillment of the Requirements for the
Degree of Masters of Science
with a
Major in Hydrology
in the
College of Graduate Studies
University of Idaho

by
Kathryn Dallas

January 2005

Major Professor: Dr. James Osiensky

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GROUND WATER TRACER STUDIES IN COLUMBIA RIVER BASALT

A Thesis

Presented in Partial Fulfillment of the Requirements for the

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with a

Major in Hydrology

in the

College of Graduate Studies

University of Idaho

by

Robin E. Nimmer

December, 1998

Major Professor: Dr. Dale R. Ralston

PERSONAL DATA

Born September 8, 1938 in Steubenville, Ohio. U.S. Citizen. Married, two adult children.

EDUCATION

University of California, Berkeley. B.S. in Forestry (1960).

University of California, Berkeley. M.S. in Forestry with emphasis in forest influences and wildland hydrology. (1962).

University of California, Berkeley. Department of Geography (1962-1963); emphasis in hydrology and geology.

University of Arizona, Tucson. Department of Watershed Management (1963-1964); emphasis in wildland hydrology.

Southern Illinois University, Carbondale. Department of Geography (1972-1973).
Emphasis in hydrology and geology.

PROFESSIONAL CERTIFICATION & REGISTRATION

Professional Hydrogeologist, Certificate Number 179, American Institute of Hydrology, Board of Registration. Granted 1983.

Certified Forester, Society of American Foresters. Granted 1996.

Professional Geologist, State of Arkansas Registration Number 1646. Issued 1991.

Professional Geologist, State of Kentucky Registration Number 1541. Issued 1994.

Registered Geologist, State of Missouri Registration Number 0989. Issued 1998.

Professional Geologist, State of Alabama Registration Number 1089. Issued 2003.

PROFESSIONAL SOCIETY MEMBERSHIPS

American Institute of Hydrology
Association of Ground Water Scientists and Engineers
Society of American Foresters
Missouri Consulting Foresters Association
National Speleological Society

HONORS AND AWARDS

1960. Pack Prize in Forestry. University of California.
1961. Membership in Xi Sigma Pi, honorary forestry society.
1972. Award for outstanding performance, United States Forest Service.

1972. U.S. Forest Service nominee for the American Motors Conservation Award.
1973. Lester B. Dill Award for significant contributions to speleology. Mississippi Valley-Ozark Region of the National Speleological Society.
1977. Chairman's Conservation Award. Mississippi Valley-Ozark Region of the National Speleological Society.
1979. J Harlan Bretz Award for outstanding contributions to the study of speleology in the state of Missouri. Missouri Speleological Survey.
1981. Outstanding Service to Education Award. Phi Delta Kappa honorary educational fraternity for southwest Missouri.
1981. Fellow. National Speleological Society.
1988. In The Name of Science Award. Springfield, Missouri Public Schools. In recognition of outstanding service and dedication to science.

EMPLOYMENT HISTORY

1973 to Present. Director and President, Ozark Underground Laboratory, Protem, Missouri. Conducts or directs consulting and contract studies in hydrogeology, cave and karst related issues, and natural resource management of karst regions.

1966 to 1973. Hydrologist, United States Forest Service. Winona, Missouri and Springfield, Missouri. Directed the Hurricane Creek Barometer Watershed study, which assessed the interactions of land use and ground water hydrology in a forested karst area. Directed Grey Hollow study. Conducted "trouble shooting work" in Missouri, Arkansas, Wisconsin, Utah, Illinois, and Indiana. Left government service as GS-12.

1964 to 1965. Chief Hydrologist, Toups Engineering, Inc., Santa Ana, California. Duties included basic data collection and analysis for plaintiffs in Santa Ana Basin adjudication and similar work for defendants in San Gabriel Basin adjudication; these were both ground water basin adjudication suits. Directed technical work on ground water basin management and artificial recharge.

1963 to 1964. Teaching Assistant, Department of Watershed Management, University of Arizona, Tucson. Aerial photogrammetry and photo interpretation.

1963. Researcher, grant from Office of Naval Research, U.S. Navy, through Department of Geography, University of California, Berkeley. Conducted field studies on the origin and hydrology of caves in Jamaica, Haiti, and the Dominican Republic. Responsible for all field work. Work resulted in 3 publications.

1960 to 1963. Teaching Assistant and Research Assistant, School of Forestry, University of California, Berkeley. Teaching in aerial photogrammetry, photo interpretation, and forest influences. Research assistant in the same fields.

SUMMARY OF EXPERIENCE

39 years of professional experience in ground water and surface water hydrology, pollution control investigations, and land management issues with particular emphasis on soluble rock landscapes. The following projects are representative examples.

1. Hydrologic studies for land management and spring protection with particular emphasis on soluble rock regions. Numerous studies of this type have been conducted for local, state, and federal agencies in Missouri, Arkansas, Alabama, Kentucky, Illinois, Tennessee, Alaska, and Wyoming.

2. Expert witness testimony on pollution potential of underground injection of hazardous wastes into deep-lying soluble rocks in Oklahoma.

3. Expert witness testimony in ground water and surface water hydrology in Missouri, Arkansas, Oklahoma, Kansas, California, Alabama, Maryland, and Indiana.

4. Expert witness testimony on riverbank stability problems in Missouri before U.S. Senate Committees at request of Senator John Danforth of Missouri.

5. Member of 6-member review panel on the adequacy of testing to determine radionuclide migration from a radioactive waste disposal site at the Idaho National Engineering Laboratory, Idaho. Served as the only hydrogeologist on the panel.

6. Member of 6-member expert hydrogeology panel on hydrological issues associated with the St. Louis Airport Radioactive Waste Site.

7. Chairman of a 4-member "blue ribbon" panel established by the U.S. Forest Service to assess the significance of cave and karst resources in southeastern Alaska. The panel also assessed the extent to which land management activities were adversely impacting the resources.

8. Hydrologic consultant to St. Charles County, Missouri on clean-up of radioactive wastes at Weldon Spring Site, a former Atomic Energy Commission processing facility. Advised on actions to protect county well field from radioactive contaminants dumped in an abandoned quarry.

9. Ground water tracing in soluble rock landscapes, and delineation of recharge areas for spring systems. Work conducted in Missouri, Arkansas, Oklahoma, Indiana, Illinois, Kentucky, Tennessee, Alabama, Florida, Georgia, Texas, Maryland, Pennsylvania, New York, West Virginia, Arizona, Oregon, California, Wyoming, and Alaska. Ground water tracing in fractured rock landscapes in New Hampshire, Alabama, New Mexico, Minnesota, Idaho, Utah, and Washington. Ground water tracing in unconsolidated geologic units in New York, Massachusetts, Florida, North Carolina, South Dakota, Missouri, Arkansas, California, Oregon, Washington, Alaska, and British Columbia (Canada).

10. Hydrogeologic investigations of groundwater impacts from pipeline corridors. Missouri, Oklahoma, and Texas.

11. Ground water tracing investigations at mines in West Virginia, Pennsylvania, Missouri, Utah, Colorado, Montana, Irian Jaya Indonesia, and Peru.

12. Hydrologic investigations to determine sources of pollutants which caused fish kills at commercial fish farms in Missouri and Arkansas.

13. Hydrogeologic site investigations (and sometimes testimony) on municipal landfills with emphasis on site suitability and probability of ground water contamination. 21 sites in Arkansas, Missouri, Wisconsin, and Alabama.

14. Hazardous waste remediation investigations with emphasis on hydrogeology. Sites in Missouri, Arkansas, Kentucky, Pennsylvania, Maryland, Alabama, Tennessee, and California. Second opinion review of projects in Missouri, Kansas, and New York.

15. Impacts of food processing wastes on surface and ground water quality. Various projects in Arkansas and Missouri.

16. Hydrologic investigations of petroleum pollution of wells. Multiple sites in Missouri, Arkansas, and North Carolina.

17. Assessment of the hydrologic impacts of proposed geothermal energy development on the Santa Clara Indian Reservation, New Mexico.

18. Investigations on the extent and sources of sewage contamination in about 100 springs at Eureka Springs, Arkansas. Work involved the delineation of recharge areas for most of these springs and the identification of sewer line segments which had the greatest leakage problems.

19. Hydrogeologic hazard area mapping for proposed sewer line corridors in a sinkhole plain area south of Mammoth Cave, Kentucky. Work included hydrologic recommendations for minimizing exfiltration and monitoring strategies.

20. Hydrogeologic mapping of Greene County, Missouri to identify areas where sinkhole flooding and serious ground water contamination could result from land development.

21. Assessment of impacts of proposed highways on springs, caves, and endangered cave-dwelling species, Arkansas, Missouri, Indiana, Virginia, and West Virginia. Similar work for airports in Missouri and Arkansas, and for coal-fired power plants in Missouri and Arkansas.

22. Identification and delineation of rare, threatened, and endangered animal species' habitats in caves and ground water systems. Studies in Arkansas, Missouri, Oklahoma, Tennessee, Alabama, and Illinois.

23. Health and safety assessment of Harrison's Crystal Cave, Barbados.

24. Health and safety assessment of natural radiation as encountered in caves open to the public in the United States. Development of industry standards.

25. Various microclimate, hydrologic, biologic, interpretive, and management investigations of caves in Missouri, Arkansas, Tennessee, Kentucky, New Mexico, Arizona, California, Wyoming, Oregon, Alaska, British Columbia, New Zealand, and Australia.

26. Evaluation of 19 sites for designation as National Natural Landmarks; sites are in Indiana, Missouri, Arkansas, Iowa, Ohio, and New Mexico.

27. Assessment of hydrologic impacts of rock quarries. Multiple sites in Missouri, Arkansas, Maryland, Illinois, Alabama, and Alaska.

28. Assessment of the impacts of deep mining on regional hydrology. Missouri.

29. Preparation of sole-source aquifer designation petition. Missouri.

30. Delineation of wellhead protection zones for public ground water supplies in Arkansas, Missouri, Alabama, South Dakota, New Hampshire, Maryland, and Florida.

31. Feasibility study for creation of a national-scale American Cave and Karst Museum.

32. Instructor in numerous professional short-courses. These have included:

1) over 20 four-day courses in karst hydrogeology and groundwater monitoring sponsored by the Association of Ground Water Scientists and Engineers and by Environmental Education Enterprises;

2) two courses on groundwater site investigation techniques for health department professionals in Washington State; and

3) courses on land management in karst terrains for resource managers in West Virginia, Indiana, Kentucky, Tennessee, Missouri, Arkansas, Utah, Idaho, Oregon, Washington, Alaska, and New Mexico.

PUBLICATIONS

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3. _____. 1963. Basic hydrographs for subsurface flow in limestone terrain: theory and application. *Cave Notes*, Vol. 5:4, pp. 26-30.

4. _____. 1964. Sea caves in the coastal karst of western Jamaica. *Cave Notes*, Vol. 6:1, pp. 1-3.

5. _____. 1964. Echinoliths--an important solution feature in the stream caves of Jamaica. *Cave Notes*, Vol. 6:1, pp. 3-5.

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12. _____. 1967. Analytical review of White, William B. and Victor A. Schmidt. 1966. Hydrology of a karst area in east-central West Virginia. *Water Resources Research*, Vol. 2:3, pp. 549-560. Review in Caves and Karst, Vol. 9:5, pp. 44-46.

13. _____. 1968. Hydrology of a karst watershed in the Missouri Ozarks. *Caves and Karst*, Vol. 10:6, pp. 49-55.

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31. _____. 1977. Springs and sewage. IN Sloane, Bruce; Editor. Cavers, caves, and caving. Rutgers Univ. Press, pp. 318-329.

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38. _____ and Danny Halterman. 1982. A conceptual characterization of the subsurface movement of toxic chemicals in soluble rock lands. *Proc. Fifth National Cave Management Symposium*, pp. 77-80.

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40. _____ and Cathy Aley. 1982. Interpretive training for show cave personnel. *Proc. Fifth National Cave Management Symposium*, pp. 91-92.

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65. Mott, David N.; Mark R. Hudson; and _____. 1998. Water resources studies, geologic mapping, and dye tracing employed to develop a model of interbasin recharge, Buffalo National River, Arkansas. *Friends of Karst, Intern'l. Global Correlation Program Abstracts.* Western Kentucky University, Bowling Green, p. 26.

66. Hauwert, Nico M.; David A. Johns; and _____. 1998. Preliminary report on groundwater tracing studies within the Barton Creek and Williamson Creek watersheds, Barton Springs / Edwards Aquifer. Barton Springs / Edwards Aquifer Conservation District and City of Austin Watershed Protection Department. 55p.

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Reference and Sources of Information

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The Ozark Underground Laboratory

The Ozark Underground Laboratory, Inc. (OUL), is a private consulting and contract studies firm which provides groundwater tracing and other hydrogeological services throughout North America. The OUL has been in continuous full-time operation since 1973 under the direction of Tom Aley, who serves as Principal Hydrogeologist for the firm. The OUL typically has a full-time staff of nine people. We are not affiliated with any academic institution, and we have no academic responsibilities which could interfere with full client service. The OUL has designed and either conducted, or assisted with, over 3,500 groundwater traces in the United States and Canada. Our clients include many environmental and engineering consulting firms; other corporate and private entities; and federal, state, and local agencies.

One common misconception is that dyes may be harmful or that they will cause some sort of public relations problem. There is extensive technical literature (such as Field et al., 1995) demonstrating that the dyes present no health or environmental problems at concentrations five orders of magnitude or more above the method detection limits of modern analytical protocols. Dye tracing does not require large quantities of dyes; the dyes discussed in this handbook are safe groundwater tracing agents.

Ozark Underground Laboratory's Groundwater Tracing Handbook
2002

- Through thousands of feet of landslide debris in Alaska.
- For several miles through lava flows in Washington.
- For hundreds of feet through fractured granite aquifers in New Hampshire and Minnesota.
- Through glacial outwash, various alluvial deposits, and deep residuum to water supply and monitoring wells.
- From highway, rail, and pipe line spill sites to streams, springs, and wells.
- From perimeter points around Solid Waste Management Units (SWMUs) at RCRA and CERCLA sites to monitoring wells and other monitored points.
- From on-site sewage systems to bulkhead drains adjacent to marine shellfish beds, Washington. Based upon 1,600 dye introductions, about 23% of the sewage systems were functioning inadequately and yielded dye to sampling stations.
- Through various deposits to verify or refine time of travel calculations for groundwater remediation.
- From leaking sewers to water supply and monitoring wells, springs, streams, and building sumps.
- From leaking impoundments to springs and wells.
- From perennial stream segments to private and public water supply wells.
- For delineating wellhead protection zones.
- For assessing groundwater scenarios where the "worst case" is flow along preferential flow routes.

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5. Field, M.S., Wilhelm R.G., Quinlan J.F. and Aley T.J., 1995, An assessment of the potential adverse properties of fluorescent tracer dyes used for groundwater tracing, Environmental Monitoring and Assessment, vol. 38, 75-96 p.

...toxicity of Rhodamine WT in rats to the known acute oral toxic dose in humans for several known acutely toxic chemicals. This comparison showed that none of the fluorescent dyes evaluated would present an acutely toxic threat at or substantially above the recommended 2 mg l^{-1} concentration.

ed for tracer tests. The lower, traditional maximum concentrations of 10 μg l^{-1} (Wilson *et al.*, 1986, p. 8; Mull *et al.*, 1988, pp. 28 and 37) have been selected primarily for aesthetic and public relations reasons, not as a result of comprehensive toxicological testing or evaluation of the dyes. A simple calculated potential dose

6. Gaikowski, M.P., Larson, W.J., Steuer, J.J., Gingerich, W.H., 2003, Validation of two dilution models to predict chloramine-T concentrations in aquaculture facility effluent, Aquacultural Engineering 30, 2004, 127-140.

The study was conducted at the aquaculture facility at the US Geological Survey's Upper Midwest Environmental Sciences Center (UMESC). The UMESC aquaculture facility continuously discharges water through two settling lagoons into a backwater area of the Black River (La Crosse, Wisconsin, USA). The mean daily discharge seasonally ranges from 1.5 to

R5 during the two, 100 Fμ/l, rhodamine WT treatments was 275 and 262 l/min. A peristaltic pump was used to meter a rhodamine WT stock solution directly into raceway R5's inflowing water stream at 2.5 l/min to maintain a concentration of 100 μg/l for 60 min. Concurrent with the application of the rhodamine WT stock solution, the water in the raceway was "charged" with 3.69 g rhodamine WT Liquid Dye (Rhodamine WT Liquid Dye, 21% active ingredient, CAS# 528-44-9, Keystone Aniline Corporation, Chicago, IL, USA) to immediately achieve an initial active ingredient concentration of 100 μg/l. After charging the raceway, the raceway water was mixed by agitation for 5 min with raceway agitators

7. Galloway, J.M., 2004, Hydrogeologic characteristics of four public drinking water supply springs in northern Arkansas, U.S. Geological Survey Water-Resources Investigations Report 03-4307, 68 p.

8. Harvey, K.C., 2005, Beartrack mine mixing zone dye tracer study outfall 001, Napias creek Lemhi county, Idaho, Private Consulting Report by KC Harvey, LLC., 59 p.

9. Kilpatrick, F.A. and Cobb, E.D., 1985, Measurement of discharge using tracers, U.S. Geological Survey Techniques of Water-Resources Investigations Report, book 3, chapter A16.

10. Marking, L., Leif, 1969, Toxicity of Rhodamine b and Fluorescein sodium to fish and their compatibility with antimycin A, The Progressive Fish Culturist, vol. 31, July 1969, no. 3. 139-142p.

> Both dyes are relatively nontoxic to fish. This is especially so in shorter exposures. A field concentration of 0.1 p.p.m. of either dye would have to be increased more than 1,000 times to be toxic to rainbow trout, a more sensitive

11. Noga, E.J., and Udomkusonsri, P., 2002, Fluorescein: a rapid, sensitive, non-lethal method for detecting skin ulceration in fish, Vet Pathol 39:726–731p.

12. Olsen, L.D. and Tenbus F.J., 2005, Design and analysis of a natural-gradient groundwater tracer test in a freshwater tidal wetland, west branch canal creek, Aberdeen proving ground, Maryland, U.S. Geological Survey Scientific Investigation Report 2004-5190, 116 p.

> ent. Fluorescein dye was injected on July 17, 1998, as 0.025 liter of solution containing 50,000 milligrams per liter of sodium fluorescein, to test the hydrologic integrity of the

13. Parker, G.G., 1973, Tests of Rhodamine WT dye for toxicity to oysters and fish, Journal of Research U.S. Geological Survey, Vol. 1, No. 4, July-Aug., p. 499.

> Wash. Tests showed that 48-hour exposures at 24° C of 11,000 oyster eggs per liter and 6,000 12-day-old larvae per liter, in sea water with concentrations of rhodamine WT ranging from 1 µg/l to 10 mg/l, resulted in development of the eggs to normal straight-hinge larvae and no abnormalities in the larvae development. Tests made on the smolt of both silver salmon and Donaldson trout, with the fish held for 17.5 hours in a tankfull of sea water with a dye concentration of 10 mg/l at 22° C showed no mortalities or respiratory problems. With the concentration increased to 375 mg/l, and the time extended an additional 3.2 hours, still no mortalities or abnormalities were noted. The fish remained healthy in dye-free water when last checked a month after the test.

An additional test was made on smolt (4—6 inches long) of both silver salmon and Donaldson trout. Eight salmon and eight trout were held in a tank of water from the aquaculture pond with a concentration of 10 mg/l of rhodamine WT dye. The fish were held in this tank for 17.5 hours with water at 22°C. No mortalities or respiratory problems were noted, and the fish appeared similar in behavior to those in the control tank. The dye concentration in the test tank was then increased to 375 mg/l for an additional 3.2 hours. Again, no mortalities or other problems were observed. The fish tested remained healthy in dye-free water when last checked approximately 1 month after the test.

14. Putnam, L.D. and Long A.J., 2007, Characterization of ground-water flow and water quality for the Madison and minnelusa aquifers in northern Lawarence county, South Dakota, U.S. Geological Survey Scientific Investigation Report 2007-5001, 73 p.

15. Quinlan, J.F. and Koglin, E.N. (EPA), 1989, Ground-water monitoring in karst terrranes: recommended protocols and implicit assumptions, U.S. Environmental Protection Agency, EPA 600/x-89/050, IAG No. DW 14932604-01-0, 79 p.

dyes generally used for tracing ground water are benign and harmless in the concentrations commonly employed (Smart, 1984).

Tracing agents are fundamental tools for discovery and prediction of the velocity and dispersal-path of pollutants in ground water and surface water. Interpretation of data from tracer studies makes it possible to protect water quality, public health, and aquatic life. Such data are crucial to the development of wellhead and springhead protection strategies and can be essential for the calibration of computer models of water flow and pollutant movement. Tracing is cost-efficient and is often the only way to get critically needed data.

A further analogy describing the use of tracing agents can be made. Doctors use vaccines and a wide range of diagnostic techniques to prevent and treat illnesses. Some of these vaccines and techniques have definite risks associated with their use. These risks are assumed by an informed patient because the consequences of not preventing or not diagnosing an illness far outweigh the slight risk from use of the vaccine or diagnostic technique.

If and when state officials establish regulations governing the use of dyes or any other ground-water tracer, they should require their use by knowledgeable, experienced professionals.

16. Smart, C. and Simpson B.E., 2002, Detection of fluorescent compounds in the environment using granular activated charcoal detectors, Environmental Geology, vol. 42, 538-545 p.

17. Spangler, L.E., and Susong, D.D., 2006, Use of dye tracing to determine ground-water movement to Mammoth Crystal springs, Sylvan pass area, Yellowstone national park, Wyoming, U.S. Geological Survey Scientific Investigations Report 2006-5126, 19 p.

18. Smart, P.L., 1984, A review of the toxicity of twelve fluorescent dyes used for water tracing, National Speleological Society publication, vol. 46, no. 2: 21-33.

Based on the experimental results reviewed above, there is no evidence of either a short or long term toxic hazard to dye users or those drinking water containing tracer dyes.

above that enduring tracer concentrations as high as 1 mg/1 would not be detrimental to aquatic ecosystems.

In conclusion, there is no evidence of significant bioaccumulation for any of the tracer dyes in fish. The most sensitive aquatic organisms to the dyes are the developmental stages of shellfish, and algae. These, therefore, determine the maximum prolonged dye concentration which can be recommended. This limit is set at 1 mg/1, well above the persistent dye concentrations commonly used in tracer tests, and at least one order of magnitude above the visible threshold. There is no evidence that short-term exposure to concentrations in excess of 1 mg/1, such as could occur transiently at injection sites, are harmful, but prior dilution should be employed if rapid dispersion and dilution of the tracer dye is not expected.

dle et al. (1983). Therefore, photo-decomposition product toxicity appears only to be a problem for Eosine.

> The acute and chronic toxicity of all the tracer dyes in mammal systems is sufficiently low that no danger should result in their use, providing normal precautions are observed during dye handling. However, only three tracers can be demonstrated to cause minimal carcinogenic and mutagenic hazard, Tinopal CBS-X, Flourescein and Rhodamine WT. Conversely, Rhodamine B is known to be carcinogenic

19. Taylor, C.J., and Greene E.A., Hydrogeologic characterization and methods used in the investigation of karst hydrology, U.S. Geological Survey field techniques for estimating water fluxes between surface water and ground water, chapter 3, Techniques and Methods 4-D2, 71-114 p.

20. Turner Designs, Inc., A practical guide to flow measurement, www.turnerdesigns.com.

21. U.S. Bureau of Reclamation Water Measurement Manual, 2001, http://www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/

22. Walthall, W.K., and Stark J.D., 1999, The acute and chronic toxicity of two xanthene dyes, Fluorescein sodium salt and phloxine B, to Daphnia pulex, Environmental Pollution volume 104, pages 207-215.

> threat to natural populations. The concentration of fluorescein necessary to elicit even a sublethal response was quite high and beyond those likely to be encountered following application to agroecosystems or in urban settings. While *D. pulex* neonates do appear to be

23. Wilson, J.F., Cobb, E.D., and Kilpatrick F.A., 1986, Fluorometric procedures for dye tracing, U.S. Geological Survey Techniques of Water-Resources Investigations of the United States Geological Survey, Applications of Hydraulics, book 3, chapter A12, 43 p.

Rhodamine WT Reader

Readings on the Reactivity and Transport Characteristics of This Tracer

Regulatory Standards

- The standards established by the Environmental Protection Agency in the Federal Register (Vol. 63, No. 40) state the maximum Rhodamine WT concentrations to be 10 micrograms per liter for water entering a drinking water plant (prior to treatment and distribution) and 0.1 micrograms per liter in drinking water.

The US Geological Survey provides the regulatory standard references for information purposes ONLY. This information was obtained in August of 2004.

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COMMERCIAL PRODUCT INFORMATION

The US Geological Survey does *NOT* endorse or recommend commercial products.
The following is provided *ONLY* for identification and information purposes.

Rhodamine WT

Sensient Corporation
  http://www.sensient-tech.com/solutions/industrial_colors.htm
  800- 558-9892

Keystone Corporation
  http://www.dyes.com/
  800-522-4dye

Fluorometers

Seapoint Sensors, Inc
  http://www.seapoint.com/srf.htm
  603-642-4921

Turner Designs
  http://turnerdesigns.com
  877-316-8049

Opti-Sciences
  http://www.optisci.com/ps.htm

603-883-4400
YSI Inc.

Model 6130 Rhodamine WT Sensor
http://216.68.81.171/852568CB0010F86A/web+by+document+type/CF82E634926142FB85256AF8005E9FCF?Open
800-897-4151

International Chemical Safety Cards

http://www.itcilo.it/english/actrav/telearn/osh/ic/37299898.htm
http://www.inchem.org/documents/icsc/icsc/eics0325.htm

Compilation by Ken Bencala and Marisa Cox, September 23, 2005
http://water.usgs.gov/nrp/proj.bib/bencala.html
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