Chair in Mine Water Remediation & Management
Prof. Dr. Christian WOLKERSDORFER

Artificial Tracer Test Legislation in Nova Scotia

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Introduction

This document is the result of an inquiry about tracer test legislation in Nova Scotia and in other Canadian Provinces. Nearly 50 colleagues commented and helped to develop the results given hereafter. At the beginning, the document describes the background of the inquiry. Then it provides general recommendations on how to proceed before an artificial tracer test is initiated. This document does *not* describe how to *conduct* a tracer test. That information can be found in the literature cited. Originally, this document was just meant to be a record of information for the Crown Corporation and the University where the artificial tracer test shall be conducted. Yet, the interest expressed by various colleagues resulted into an extension of the "record" into a small "guidance document".

Cape Breton University, through its Research Chair in Mine Water Remediation and Management, plans to conduct an artificial tracer test in a local brook (Cadegan's Brook) on Cape Breton Island, Nova Scotia, Canada. This brook flows above a number of interconnected and flooded coal mines referred to locally as the 1 B Mine Pool. Previous investigations by the former mine operator and the Research Chair indicated that there might be a connection between the brook and the abandoned mine workings. To clarify the situation the Research Chair wants to conduct an artificial tracer test in the brook.

Since the Research Chair was not aware of the necessary permits required in Nova Scotia, about 80 e-mails to colleagues in Canada were sent out and the following question asked:

> "I plan to conduct a mine water tracer test here in Nova Scotia, but I am unaware of the permits necessary to conduct tracer tests. I already asked a number of people on Cape Breton Island, but nobody knows what would be necessary.
>
> The tracer tests I aim to conduct shall investigate the flow regime within a mine pool. In addition, I want to investigate the flow regime within a local brook, because we noticed that some of the water in this local brook seems to re-infiltrate into the mine pool.
>
> Do you know, which legislative measures are necessary to have a surface/mine water tracer test approved? Or do you know of any resources or colleagues I could ask?"

Results

Environmental aspect of an artificial tracer test

From an environmental point of view the excess use of artificial dye tracers should be minimized. In most cases only several grams to decagrams of tracer are necessary to get good breakthrough curves. Using dye tracers for a *visual* inspection of the potential flow path should certainly be avoided. Frequently, natural tracers can be as good as or even better than artificial ones. Therefore, a conceptual hydrogeological model and a good water sampling programme including natural tracers should always be set up before an artificial tracer test is performed. Using the data of the conceptual hydrogeological model ensures that no more tracer than necessary will be injected into the environment.

General findings about tracer test legislation

The range of answers that arrived was interesting, as most indicated that no artificial tracer test permits would be required in Canada. This situation is similar to the US, where only a few states have tracer test guidelines or regulations (Holmbeck-Pelham et al. 2000). Based on the answers, the only province which has a tracer test guideline seems to be Alberta, which has a nine pages document, the "Tracer-Dye Study Guidelines – Water Quality Branch Standards and Approvals Division, Alberta Environment, December, 1991", in force. In addition, persons conducting artificial tracer tests are requested to follow the "Environmental Code of Practice for Hydrologic Tracing Analysis Studies" (Government of Alberta 1996). From a practical point of view, this code seems to request too much detailed information, though it is convenient for a regulator to have such a guideline. Taking into account that every tracer test differs from the other, a more general guideline which will be evaluated by just one regulatory body would be of more help. Especially for researchers the Alberta Code of Practice is cumbesome.

In Europe the situation is different, based on EU water legislation. Germany, for example, prohibits the use of water and the injection of substances into any kind of water body. Artificial tracer test permissions are based on procedures according to § 2 (1) and § 3 (1) No 5 of the German Water Budget Law. The water authority might permit those tests based on § 7(1) with conditions based on § 4(1) of the German Water Budget Law (see also Wolkersdorfer 2008 for details). Currently, there is no approved procedure for the permitting process, but authorities commonly follow the Bavarian guidelines for artificial tracer tests (Schwarz et al. 2002) and the recommendations given in Käss (1998).

Some Canadian colleagues indicated that they use comparable large quantities of tracer and the Alberta guidelines seem to refer to a visual inspection of the dye tracer as well (in this case they are referring to Rhodamine WT). However, water tracers are usually fluorescent tracers and have very low detection limits. Their excess use should therefore be restricted and only that amount of tracer used that is necessary to be above the detection limit. Field (2003) published a document about the Efficient Hydrologic Tracer-Test Design (EHTD) software with which the appropriate tracer amounts for analytical inspection can be calculated.

Specific requirements for Nova Scotia

Obviously, there are three authority levels in Nova Scotia that need to be considered when conducting a tracer test:

- Nova Scotia Environment
- Department of Fisheries and Ocean
- Environment Canada

All three authorities replied to the above cited e-mail and indicated that artificial tracer tests with tracers that are assumed to be non-toxic don't need an approval. This does not apply for artificial tracer tests with radioactive substances. According to the web page of the Canadian Nuclear Safety Commission (CNSC) they need formal approval.

Here are the relevant portions of the answers from the above mentioned authorities (their complete e-mails are attached at the end of this document):

> "I understand that you were also in contact with a coworker of mine, Malcolm MacNeil, regarding the proposed work. He also indicated no approval required from NSE" (Ian M Campbell, NS Environment, 2011-02-10)

> "We would not issue a permit, but we would take a look at the proposal to ensure that there would be no ill effects and ensure proper mitigation is in place (make-up of the tracer to ensure that it would not be harmful to fish would be our main concern)." (Kurt McAllister, Department of Fisheries and Oceans, 2011-03-08)

> "Environment Canada is responsible for enforcing Section 36 of the Fisheries Act. That Section prohibits the deposit of any substance that is deleterious to fish into waters frequented by fish. There is however no need for a permit from Environment Canada for the use of a tracer in a brook if the tracer is used at a concentration that isn't deleterious to fish." (André Gauthier, Environment Canada, 2011-03-02)

One colleague pointed out the "2011 Metal Mining Environmental Effects Monitoring (EEM) Technical Guidance Document" which includes recommendations for a "Field Tracer Study" in the "Additional Technical Guidance – How to Conduct Effluent Plume Delineation". This document, meanwhile, has been updated and was published in 2003 (Murdoch et al. 2003). Though it is not exactly about artificial tracer tests in streams, it can be used as guidance document to some extent. Another guidance document was published by Environment Canada (2005). Yet, this one contains somewhat incorrect information about rhodamine WT and Na-fluoresceïn (they wrongly write fluoresceïn; the better term is uranine). Of the two, uranine should be the tracer of choice, not rhodamine WT, because uranine has a lower detection limit, adsorbs less to soil (Smart & Laidlaw 1977), and is less toxic than rhodamine WT (Field et al. 1995, Behrens et al. 2001; Käss 2004). In addition, uranine's photodecomposition in real surface water bodies is less significant than usually described (Tonogai et al. 1979) because the tracer is partly protected from photodegradation by a water column of at least a couple of centimetres. Therefore, uranine can be used without difficulty for surface tracer tests with a duration of several hours.

There are several papers available about the potential toxicity of artificial tracers for water tracer tests. One of the best known might be Smart (1984) and Field et al. (1995), but the latest one has been published by Behrens et al. (2001). Good procedure would be to provide the regulator information of any sub-lethal, chronic toxicity information on the tracer compound (Holmbeck-Pelham et al. 2000).

Suggested Approval Requirements

No matter in which Province or country an artificial tracer test is carried out, a meeting with or a telephone call to the before mentioned authorities should be arranged. During that meeting the authorities should be informed about the tracer test's objectives and questions relating to potential concerns should be raised.

Because there is no standard procedure for artificial tracer test approvals in Nova Scotia, the Research Chair recommends using the following simplified structure to describe the artificial tracer test to the authorities. It is adapted from a list given in Wolkersdorfer (2008):

- district and place name including map and map reference
- person in charge of the tracer test with phone numbers
- customer with full address
- purpose of the tracer test
- type of tracer including CAS number, expected dilution, and LD_{50} data
- description of the injection sites including map
- a list of the sampling sites including map and sampling intervals
- water quantities to flush the injection site and the tracer including where water will be drawn from
- start of tracer test including begin and end of tracer injection
- necessary measurements on site
- work schedule for continuous sampling
- work schedule for analytical laboratory
- emergency plan including contact phone numbers

Regardless, the appropriate regulators should be asked for "guidelines", or if there is no regulatory guideline, regulators should confirm they have no objection to the proposed tracer tests being carried out. In addition, it might be helpful to provide some examples where the tracer compound has been previously used and include any published papers on the specific tracer compound.

Terminology Remarks

Historical reasons are responsible for the fact that each tracer has numerous different names. In most cases, tracers can easily be identified by looking into those synonym lists. Yet, for fluoresceïn, this is not as straight forward as for other tracer substances. Wolkersdorfer (2011) therefore outlined the following terminology considerations:

"Concerning the term Na-fluorescein, there seem to be some misunderstandings in the English literature, because many reports have used the word fluorescein when the author actually used Na-fluorescein (Quinlan 1989). Only the latter is used for water tracer tests, because it has fluorescent characteristics that can be used to analyse even extremely low concentrations in water. Moreover, fluorescein has a very low water solubility (L = 0.05 g L^{-1}) compared to that of uranine (L = > 600 g L^{-1}; Heumann & Friedlaender 1888; Käss 2004). This might explain why some authors report poor recovery rates for fluorescein and recommend rhodamine WT instead; they likely used the wrong fluorescein. Both substances have the same colour index (C.I. 45350), which might have caused confusion in the past, but they have different Chemical Abstracts Service (CAS) registration numbers (fluorescein: 2321-07-5; Na-fluorescein: 518-47-8). In the German literature, Na-fluorescein is called *Uranin*, thus preventing confusion, and Rhodamine WT is seldom recommended. To avoid future confusion in water tracer tests, the term fluorescein should be avoided when Na-fluorescein is meant and, as was the case before the Second World War (Google labs 2011), the term uranine should be used instead."

Chemically, uranine is the di-sodium salt of fluoresceïn ($C_{20}H_{12}O_5$) and has the molecular formula $C_{20}H_{10}Na_2O_5$. Because the fluorescent intensity of uranine is pH dependent, the fluorescence must be carefully measured within well buffered pH ranges or calibrated at the expected pH value during the tracer test.

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I hope that this document will be a useful guide for colleagues who plan to initiate an artificial tracer test in Nova Scotia and beyond. In addition, I hope that it will be a helpful tool for the authorities who are responsible for protecting the Canadian environment.

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