한국지하수토양환경학회 춘계학술발표회
2006년 4월 14일 동국대학교

Application of activated carbon bugs to the dye tracer study in a Karst area

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요 약 문

Studies were performed on evaluating the applicability of activated carbon bugs on dye tracer tests as tracer detectors by using its adsorption isotherm of the grained activated carbon. We preliminary conducted several standard adsorption and extraction tests and obtained the relationship between standard dye solution and detected concentrations from activated carbon samples in dry and wet conditions. the slopes of the regression line were 0.71 for wet condition and 0.74 for dried one. Field dye tracer tests were performed in a karst area, where several faults occur along a stream and pass the test area. We sampled water samples and activated carbon samples at three points in Hwangji Pond, where groundwater outflows from the karst conduit. According to the results of breakthrough curve analysis, the regional flow along the conduit, which is assumed to cause a karst conduit, was estimated as 0.18 m/day. The relationship between the concentrations of water sample and extracted activated carbon bugs shows the similar slopes with those from standard solution tests. This suggests that activated carbon could be useful as a dye tracer detector because the extraced concentration can be quantified.

key word : activated carbon, dye tracer test, karst conduit

1) Quantitative Analysis

In the case of evaluating the mass of dye absorbed on the activated carbon bugs, which are withdrawn from field site, it is likely that variable extracted masses resulted from various factors cause such as conditions of activated carbon bugs, dried or wet, injected concentrations of dye tracer, and adsorption isotherms. It is necessary that the quantitative analysis of dye extraction from the surfaces of the charcoal. The quantitative analyses were conducted under the following conditions. 1) 20 g of activated carbon was immersed in standard dye solutions, Rhodamine WT and fluoresceine, prepared in each standard dye solutions, 40 mL, for 24 hours. The concentrations are : 0.0 μg/L, 0.01 μg/L, 0.1 μg/L, 1.0 μg/L, 10.0 μg/L, 100.0 μg/L, 1000.0 μg/L, and 10000.0 μg/L. 2) The activated carbon bugs were divided into two conditions: air-dried and wet samples using 10 g of activated carbon. 3) Each activated carbon was soaked in 20 mL of smart solution for 24 hours. The smart solution consisted of ammonium hydroxide (38%), 1-propanol (43%), and distilled water (19%). 4) A 10-AU fluorometer was used to measure the concentration of dye tracer extracted from the charcoal surfaces.

2) Standard Calibration Curves

The standard calibration curves for dye tracers (rhodamine WT and uranine) were obtained through the quantitative analysis. The wet activated carbon bugs show relatively higher concentration than dried ones. It is thought that the dye tracer was entrapped into the pores between activated carbon particles when the activated carbon bugs were taken out of standard tracer solutions. However, Both the slope of the regression lines for them were within acceptance criteria, which was within 20 percent of each value. For the rhodamine WT calibration curve of the activated carbon, the extracted concentration from standard solution, 0.1 ~ 1.0 µg/L, ranged from 0.037 to 0.140 µg*/L* for the wet condition and from 0.060 to 0.628 µg*/L* for the air-dried condition. The extracted dye concentration sharply increased as the standard solution was 1.0 ~ 1.0×10^5 µg/L. For the uranine calibration curve of the activated carbon, the extracted concentraion ranged from 0.672 to 2890.0 µg*/L* (wet activated carbon) and from 0.363 to 2660.0 µg*/L* (dried activated carbon).

The extracted uranine concentrations for each standard solutions showed the same range of those for Rhodamine WT. For the both dye tracers, log-log relationship with standard concentration was found for extracted dye tracers from activated carbon bugs. The slopes of the best fit line of standard solution vs. detected concentration of Rhodamine WT were 0.76 and 0.79 for wet and dried conditions, respectively. For the uranine dye tracer, the slopes between standard solution and extracted concentrations were 0.71 for the wet condition and 0.74 for the dried condition. These similar slopes suggested that using any condition of dye tracer would not affect its slope but rather its intercept. The intercepts of the regression lines for Rhodamine WT were similar to each condition, -1.06 (wet) and -1.41 (dry). However, those of uranine showed comparatively larger differences between wet and dried conditions, 0.36 and -0.41, respectively. The results of these relationships were used to determine the breakthrough curves and characteristics of the carbon bugs.

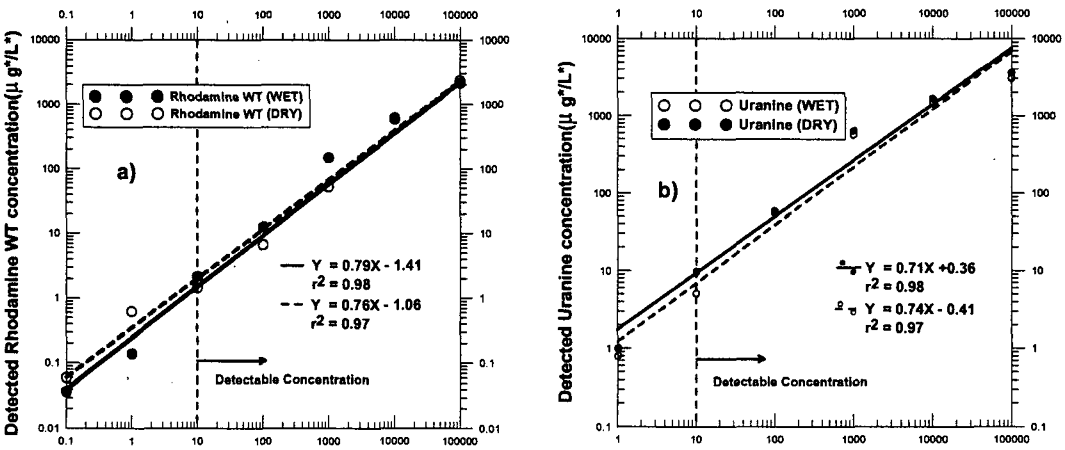

Figure 1. Log-log relationship of standard solution and extracted dye tracer from the activated dye tracer. a) Rhodamine WT and b) Uranine.

1)µg*/L* : extracted concentration from 20 ml of smart solution and 10 g of activated carbon grains.

3) Dye Tracer Test Design

The study area, Taebaek city, is located on the southeast of Kangwon-do province, Korea (Figure 2). It is underlain by Maggol limestones of Ordovician age. the dye tracing study was conducted in the Maggol limestone formation. Above the formation in stratigraphic order within the Taebaek city are shale and sand stone layers, recent river deposits. Four faults strikes N70°W, N76°W, N82°E, and N17°E and have produced karst conduits which are preferential flow routes of groundwater in this area. Among them, a fault striking N70°W directs toward Hwangji Pond. The tracer injection was conducted at a point, which the fault and Jeolgolcheon stream are intersected each other. Uranine was injected into the bottom of well MH1 at a depth of 16.3 m. The injection was conducted at a flow rate of 1.67 L/min for 3.5 hours. Groundwater and surface water including pond was sampled on November 7 and 14, before performing the dye tracer test. In addition, activated carbon bugs were installed in the Hwangji Pond to estimate background concentration of the study area. The background concentration obtained from background samples was from 0.0 to 0.087 μg/L. The location at which groundwater samples and activated carbon bugs were collected during the dye tracer test is shown on Figure 2. The groundwater and activated carbon samples were collected from 3 locations, where the inflow of groundwater through the karst conduit was presumed to occur in Hwangji Pond. The injection well and sampling points were about 994 m apart. The water samples were collected once every 8 hours before detecting the tracer at the pond, but the sampling frequency increased during the tracer detection period.

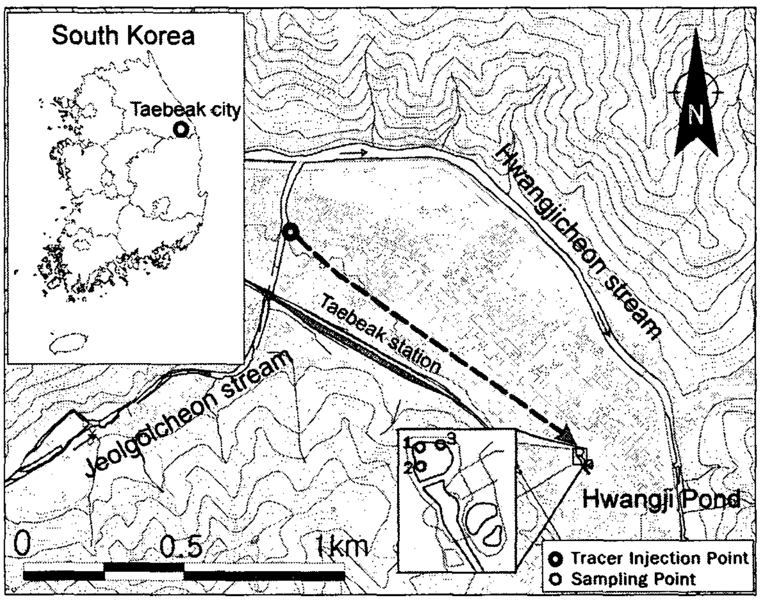

Figure 2. Location of dye tracer study area

4) Results and Discussions

The results of this dye tracer study provide some hydrogeologcial factors, which are the interconnection between injection well and Hwangji Pond and the groundwater flow rate through karst conduit formed by faults. As shown in Figure 3, the breakthroughs from three sampling points were same with time. It can be assumed that the three points in Hwangji Pond are connected with the karst conduit. Tracer was detected at the sampling points 2.2days later. The time taken from the start of tracer detection to peak arrival was about 1.49 days. the concentration at the peak was about 138 µg/L. The maximum concentration at the braekthrough curve at Hwangji-3 was about 5.52×10^{-4} times lower that the initial concentration. According to the center of mass arrival time, the groundwater flow rate along the fault line was assumed as 0.18 m/min. The breakthrough curve also shows 1.49 days of tailing period, which is about 4.28 times longer than peak-arrival period. The activated carbon bugs were installed and collected for three times during the tracer test. Each periods of sample collection were March 15 ~ 16, March 16 ~ 17, and March 17 ~ 18, 2006 and the duration from installing and collecting of activated carbon sample was about one day. As mentioned before, we used 10 mL of smart solution to extract the dye tracer absorped on 10 g of the activated carbon grains. The extracted concentrations of the tracer at each sampling points were similar with each other as shown in the breakthrough curves obtained from water samples. For the dried activated carbon samples, the ranges of concentration at Hwangji-1, Hwangji-2, and Hwangji-3 were 2.66 ~ 36.6 µg*/L*, 0.242 ~ 40.5 µg*/L*, and 0.928 ~ 83.7 µg*/L*, respectively. For the wet condition, those from Hwangji-1 to Hwangji-3 were 6.5 ~ 81.3 µg*/L*, 0.878 ~ 86.9 µg*/L*, and 2 ~ 162 µg*/L*, respectively. The results from wet condition show about three times higher concentration than those of dried conditions. The best fitting line for dried condition has a slope of 0.68 and an intercept of (1.26, 3.52 µg*/L*). For wet condition, both the slope and the intercept of the regression line are 0.71 and (0.28, 1.32 µg*/L*), respectively. The slopes from field tests were similar with those from sandard tests. This suggests that the relationship between dye concentration of water sample and extracted concentration from activated carbon grains has a slope of 0.68 ~ 0.74.

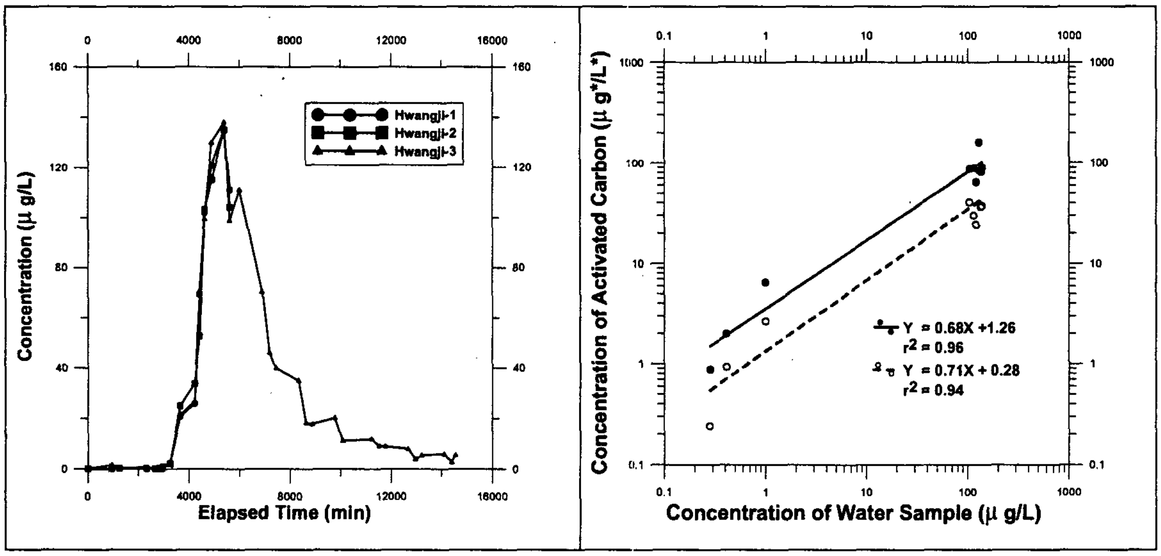

Figure 3. Results of dye tracer test a) Breakthrough curves obtained from water samples b) Log-log relationship from the activated carbon samples.