PROJECT SUMMARY

Title:	**F Test for Natural Attenuation in Groundwater: Application on Benzene**
Project I.D.:	R/UW-REM-008
Investigator(s):	Principal Investigator(s): ***Fe S. Evangelista***, Associate Professor, Mathematical and Computer Sciences Department, UW-Whitewater ; ***Aristeo M. Pelayo***, Hydrogeologist, RR/3, WDNR
Period of Contract:	July 1, 2002 – June 30, 2003
Background/Need:	Chapter NR 726, Wis Adm. Code, allows closure of a petroleum site contaminated above NR 140 groundwater enforcement standards when natural attenuation (NA) has been demonstrated as an effective remedial option. The primary evidence for NA is contaminant concentration data that show a decreasing trend over time. However, the concentrations may be affected by the fluctuation of the water table such that conclusions from trend analysis and rate of degradation may be premature. A statistical F-test procedure was developed to determine the significance of water-table fluctuations in evaluating NA sites .
Objectives:	To investigate the utility of an F-test in analyzing the statistical significance of including both groundwater elevation and time as predictors of benzene concentration. The conclusions of the test would be compared to the conclusions from the Mann-Kendall and Mann-Whitney nonparametric tests.
Methods:	Data from the web-accessible WI GIS registry of closed sites were reviewed. Sites were chosen based on the presence of both groundwater elevation and benzene concentration data, and the absence of any active remediation system during the monitoring period. The data was analyzed using the F-test technique, the calculation of the apparent half-life $t_{1/2}$, (*negative* when benzene is increasing) from the slope of the *'t'*-only regression line; and trends concluded from two nonparametric tests–Mann-Kendall (M-K), and Mann-Whitney U (M-W)–for wells where a negative $t_{1/2}$ was obtained.
Results and Discussion:	Thirty wells were chosen from 25 NA sites. Twelve (12) wells were identified where the F-test concluded that the

line '*t*'-only model is preferred. This implies that straightforward trend analysis of the concentration data is acceptable for these wells. Fifteen (15) sites had wells where at least one of the following was observed: (a) the value of $t_{1/2}$ is negative indicating an increasing trend, (b) the plane model or line '*z*' model is preferred by the F-test, or (c) the F-test is inconclusive but the line '*z*' model's R^2 is larger than that for the line '*t*' model. The latter two conditions imply that the variable 'z' cannot be ignored and points to the influence of groundwater elevation on benzene concentration. Consequently, the time-trend analysis of the data, including conclusions from nonparametric statistical tests may be spurious. The report includes a detailed analysis of four sites to demonstrate the range of results and insights that can be gained in using the F-test technique.

Conclusions/Implications/ Recommendations:

The F-test is an analytic tool that could be used to screen sites before the calculation of a degradation rate from the linear regression of concentration *vs.* time or the use of a nonparametric test to show trends. When the F-test shows that groundwater elevation is significant (plane, '*z*'-only, and inconclusive but '*z*'-only has larger R^2), then we know that this *invariant* factor is affecting the concentrations; and hence, a nonparametric test is not appropriate. On the other hand, when the F-test shows that '*z*' can be ignored (*i.e.*, test result of either: '*t*'-only , or inconclusive but the '*t*'-only has larger R^2), then nonparametric statistics may be more appropriately used.

Key Words: Benzene, Least-square regression, Natural Attenuation, Statistical F-Test

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