Appendix D

Correlation Equations for Converting Between Fecal Coliform and *E.* Coli

Ohio EPA Bacterial TMDL Correlation Equations for Converting Between Fecal Coliform and E. Coli

Modeling and Assessment Section December 2006 Division of Surface Water

Ohio Environmental Protection Agency

COLUMBUS

The Ohio EPA revised rule in progress will include E. coli as the primary applicable indicator for recreational use in place of fecal coliform. The approval of the new rule will require revisions to TMDL bacteria implementation. Nearly all of EPA's TMDL bacteria models and tools, such as the EPA BIT spreadsheet, are designed for fecal coliform modeling. In the absence of a mathematical model to allocate E. coli, therefore, a method is needed to calculate E. coli TMDLs by using a fecal coliform model and an in-stream translator.

Bacteria Translator Work By Other States

Several other states have already developed U.S. EPA-approved bacteria translators for E. coli and fecal coliform. These include the Oregon Department of Environmental Quality[1] and the Virginia Department of Environmental Quality[2], whose regression equations have been accepted by USEPA Regions 10 and 3, respectively, for TMDL development. Oregon is using the equation, $E.\ coli = 0.531\ FC^{1.06}$, while Virginia has developed the equation, $E.\ coli = 0.988\ FC^{0.919}$.

Data Screening

Fecal coliform and E. coli samples for the Northeast District of Ohio EPA are analyzed by a contract laboratory. The Central, Southwest, and Southeast Districts of Ohio EPA use a central OEPA laboratory. (Due to contract lab limitations, the Northwest District has sampled for E. coli much less than the other districts, and its results were not included. A regression analysis of Northwest District data may be conducted in the future, when more data will be available.)

Prior to running the correlation analyses, fecal coliform - E. coli paired data were screened using the following criteria:

- Non-detects were deleted (if either value in the pair was non-detect).
- Values which were too high to be quantified were also deleted (if either value in the pair was too high).
- Data with problems noted on the lab sheet were removed (e.g., holding time too long or values estimated).
- Only data from the recreational season (May 1 to October 15) were used.
- Only stream samples were analyzed (i.e., no outfalls).
- "Bad" ratios (E. coli / Fecal Coliform > 1) were assumed to be due to random error and left in.

Due to the possibility of differences in laboratory techniques between Ohio EPA's central lab and the Northeast District contract lab, fecal coliform - E. coli correlation equations were determined separately to check for any significant differences in these equations.

Correlation Methodology

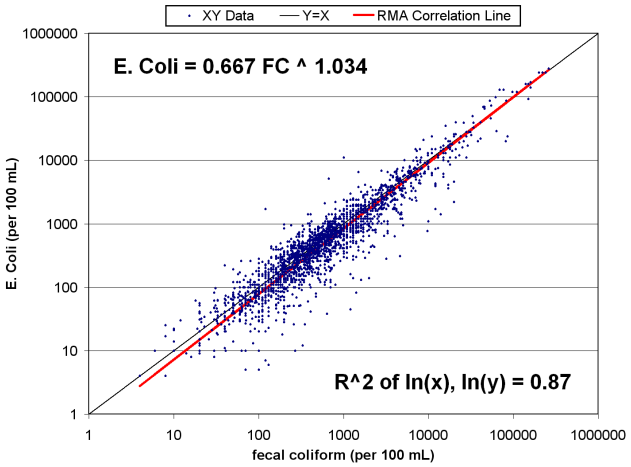
For the Northeast District, 2183 pairs of fecal coliform - E. coli were evaluated. For the Central, Southeast, and Southwest Districts, 4874 pairs of data were analyzed. The fecal coliform - E. coli pairs were log-transformed prior to the correlation.

Simple linear regression (also called "Ordinary Least Squares", or "OLS") is not recommended if there are errors in the 'X' values as well as the 'Y' values[3,4]. Also, it may be necessary during TMDL development to convert back and forth between fecal coliform and E. coli, and simple linear regression results in two non-equivalent equations depending on which parameter is used as the 'X' value and which is used as the 'Y' value. For these reasons, a "Type II" regression was performed.[4-6] "Type II" regressions create a unique functional relationship between two variables, regardless of which is the dependent and independent variable.

Results

The differences in the equations for the Northeast District contract lab and Ohio EPA's central lab were deemed significant enough[7-8] that two separate equations are recommended. For TMDLs in the Northeast District of Ohio, the regression equation is calculated to be:

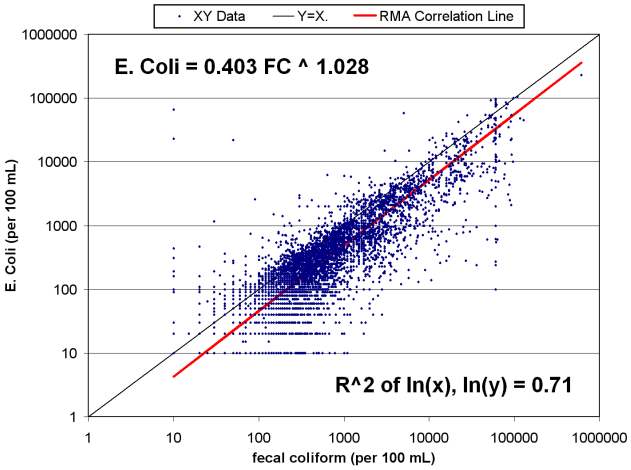
$$E.\ coli = 0.667\ (fecal\ coliform)^{1.034}$$



Results for OEPA Northeast District

For TMDLs in the rest of Ohio, the equation is:

$$E.\ coli = 0.403\ (fecal\ coliform)^{1.028}$$



Results Excluding OEPA Northeast District

References

1. Cude, Curtis G., "Accommodating Change of Bacterial Indicators in Long Term Water Quality Datasets," Journal of the American Water Resources Association, Paper No. 02144, February 2005, pp. 47-54.

2. "HSPF Model Calibration and Verification for Bacteria TMDLs," Guidance Memo No. 03-2012, Commonwealth of Virginia, Department of Environmental Quality, Water Division, September 3, 2003, p. 4.

3. Sokal, R. R. and Rohlf, F. J. 1995. Biometry: The Principles and Practice of Statistics in Biological Research (third edition). W. H. Freeman, New York.

4. Isobe, Takashi, Feigelson, Eric, Akritas, Michael, and Babu, Gutti Jogesh, "Linear Regression in Astronomy I", The Astrophysical Journal, 364:104-113, November 20, 1990.

5. Helsel, D.R., and Hirsch, R.M. Statistical Methods in Water Resources, Techniques of Water-Resources investigations of the United States Geological Survey, Book 4, Hydrologic Analysis and Interpretation, Chapter A3, U.S. Geological Survey, U.S. Department of the Interior, September 2002, Chapter 10.

6. This report used "reduced major axis" (RMA) regression. There is some evidence that "OLS Bisector" is the best Type II regression method, but the statistical software that was used in developing this report ("SMATR") contains no tests for this method. However, the RMA regression equations in this case are nearly identical to the OLS Bisector equations.

7. Warton, DI, IJ Wright, DS Falster, and M Westoby (2006) "Bivariate line-fitting methods for allometry." Biological Reviews 81(2):259-291.

8. Falster, DS, DI Warton, and IJ Wright (2006) SMATR: Standardised major axis tests and routines, ver 2.0. http://www.bio.mq.edu.au/ecology/SMATR/.