Environmental Science & Technology

CORRESPONDENCE/REBUTTAL

pubs.acs.org/est

Comment on "Trend Reversal of Nitrate in Danish Groundwater—A Reflection of Agricultural Practices and Nitrogen Surpluses since 1950"

Hansen et al.[1] conclude in their paper "regulation and technical improvements in the intensive farming in Denmark have succeeded in decreasing the N surplus by 40% since the mid-1980s, while at the same time maintaining crop yields and increasing the animal production of especially pigs. Trend analyses prove that the youngest (0−15 years old) oxic groundwater shows more pronounced significant downward nitrate trends (44%) than the oldest (25−50 years old) oxic groundwater (9%). This amounts to clear evidence of the effect of reduced nitrate leaching on groundwater nitrate concentrations in Denmark."

I believe that there are at least two problems with these conclusions that make them doubtful. The first problem relates to the ultimate interpretation of results shown in Table 1 regarding "clear" evidence of reduced leaching and the second problem relates to methodology used to obtain results of areal trends shown in Figure 3 that show overall decreases in concentrations of nitrate after about 1980. These two problems are discussed in order below.

1. Context of interpretation for results shown in Table 1.
   A major conclusion of the paper relating to Table 1 is misleading. The interpretation implies that reduced applications of fertilizer and better management practices have resulted in decreasing nitrate concentrations in groundwater, observable since the 1980s. Compared to the oldest water (>25 years), this is statistically true, as shown in the subsequent explanation. The more important question for environmental managers is, however, are there more decreasing trends *currently and in the recent past (post mid-1980s)* than "increasing" or "no trends" that reflect reduced leaching of nitrate to groundwater? Although it is true, on the basis of a simple Chi-square analysis of downward and no trends, that water younger than 15 years old had significantly higher percentage occurrence of decreasing trends than water older than 25 years (44% vs 9%), there is no statistical difference at a significance level of 0.05 between the occurrence of upward, downward, and no trends in the 0−15 year old water (χ-square = 5.927, df = 2, p-value = 0.0516) or in the 15−25 year old water (χ-square = 3.219, df = 2, p-value = 0.1998). *Thus, based on the data shown, there are no more downward than upward or no trends in the data occurring in either of the younger waters, providing no quantitative basis to say concentrations are currently decreasing in response to any factor.*
   Therefore, although there are more downward trends in both of the younger waters compared to the oldest, basically this is what we already know and has been documented in many studies: that groundwater nitrate concentrations were increasing beginning in the 1950s and that increases may have peaked after the 1980s. What we do not know, and this paper has not demonstrated, is whether nitrate may still be increasing, staying the same, or decreasing. However, the answer to the question "Are there more decreasing trends in younger water that reflect impact of changes in management?" based on the data shown in Table 1, is "no".
2. Methodology and decreasing trends presented in Figure 3. This particular figure would be quite compelling were it not for critical deficiencies including the (a) unequal distribution of sampling points through the period and (b) inappropriate application of a moving average. In addition, the decrease in nitrate concentration before any implementation of remedial actions is not explained, and the phenomenon by itself should have been key to the authors re-examining the data set and how it was analyzed. There also was no discussion about possible changes in lab methods relating to accuracy and precision of determinations that could have been wrongly interpreted as trends due to other factors, and no justification for outlier removal was given.
   a. Unequal distribution of sampling points through time and space
      Most problematic is the use of unequal number of sampling points through time and space. The first decade (1950−1960) has only about 5 points. By around 1995, there are 3 or 4 points, considerably fewer (and different) than the area represented in 1980s, where there are at least 10 points or more for several years. Although it is not absolutely necessary that each year have exactly the same sampling points, it is necessary that the same areas are represented every year; clearly, this is not possible with one or two points some years and ten or twelve in others. In short, the area and recharge time representation is not consistent for the period of analysis. If the area toward the end of the record is different from the beginning and middle, any resulting statistics analyzed for trend would be meaningless.
   b. In addition to unequal space and time representation, the concentrations of nitrate do not appear to be normally distributed and skewed. A running mean, sensitive to outliers, was used instead of simpler and more reliable estimator such as the median, which can be analyzed by nonparametric methods. If the concentration values are not normally distributed, the probabilities of occurrence associated with the sample mean are incorrect and confidence intervals are likewise incorrect. A statistically legitimate way to analyze the data would be to simply group the data by recharge period (assuming again, that the areas represented are the same for all

Published: April 01, 2011

dx.doi.org/10.1021/es200441v | *Environ. Sci. Technol.* 2011, 45, 4187–4188

three periods), compute the basic statistics for the three periods, show the median and confidence intervals for the nitrate concentrations, and use a Kruskal−Wallis test[2] to answer the question "Are there significant differences between the time steps?" Another method would be to apply a LOWESS smooth curve to these data that would give a reasonable indication about trend (both upward and downward). A Spearman rho correlation analysis[2] of the data split before and after the approximate middle of the entire period, could also have legitimately be applied to determine upward, downward, or no trends.

With non-normally distributed nitrate concentration data, inappropriate use of an estimator such as the mean and uneven distribution through time and space of data points, the conclusions of the article are questionable in their present form.

Timothy B. Spruill
*Hydrologist**
U.S. Geological Survey North Carolina Water Science Center, 3916 Sunset Ridge Road, Raleigh, North Carolina 27607, United States

AUTHOR INFORMATION

Corresponding Author
*E-mail: tspruill@usgs.gov.

DISCLOSURE

The author's stated views are his own and do not reflect the views of the U.S. Geological Survey.

REFERENCES

(1) Hansen, B.; Thorling, L.; Dalgaard, T.; Erlandsen, M. Trend reversal of nitrate in Danish groundwater—A reflection of agricultural practices and nitrogen surpluses since 1950. *Environ. Sci. Technol.* **2011**, *45*, 228–23410.1021/es102334u.

(2) Conover, W. J. *Practical Nonparametric Statistics*; John Wiley and Sons: New York, 1980; 493 pp.