UK Technical Advisory Group on the Water Framework Directive

Derivation of Nitrate Threshold Values for Assessing Risks to Groundwater Drinking Water Resources

This Guidance Paper is a working draft defined by the UKTAG. It documents the principles to be adopted by agencies responsible for implementing the Water Framework Directive (WFD) and the Groundwater Directive in the UK. This method will evolve as it is tested, with this draft being amended accordingly.

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Groundwater Nitrate Thresholds Values

Key points and Groundwater Task Team (GWTT) recommendations

1. GWTT has addressed the concerns arising from the application of different threshold values for nitrate across the UK during the first cycle of river basin planning. The different values resulted from the application of the peer reviewed methodology applied during the first cycle.
2. GWTT has developed and tested a new typology-based approach to deriving threshold values. This is described in the summary paper below.
3. GWTT has reviewed the outputs of the testing work and recommends that a typology-based approach is not adopted for the second river basin management planning cycle as the results indicate that different threshold values cannot currently be defined or be justified for different environmental (hydrogeological) settings.
4. GWTT also recommends that a single threshold values of 37.5 mg/l (as NO_3) is adopted for nitrate across the UK in the absence of being able to apply an alternative scientifically robust methodology at this time. This value is derived from applying existing UKTAG guidance on groundwater chemical classification[1] (Annex II, Option two). GWTT believes that this is the most proportionate way of balancing the need for a single standard with the way in which the standard will be used.

Evaluation of a typology based method for deriving nitrate threshold values (TVs) for groundwater

Introduction

Following the publication of the first River Basin Management Plans and in response to queries about the differences in nitrate threshold values, the UKTAG Groundwater Task Team has re-evaluated the methodology for calculating threshold values. This re-evaluation has taken into account the range of hydrogeological conditions across the UK and Ireland and the susceptibility of groundwater bodies to pollution by nitrate.

The objective of the work was to consider the potential for applying a consistent typology-based approach for deriving threshold values across the UK and Ireland and propose new threshold values for the second cycle of river basin planning. These threshold values would apply only to the Drinking Water Protected Area Test and General Chemical Test as part of groundwater classification (status assessment). Threshold values for the Groundwater Dependent Terrestrial Ecosystem Test and Surface Water Chemistry/Ecology Test are not considered as they are derived in a different way (see UKTAG Guidance – Paper 11b(i) [1]).

Background

For the first river basin planning cycle, different nitrate threshold values were defined by England, Scotland, Northern Ireland and the Republic of Ireland for protecting drinking water (Drinking Water Protected Area Test) and for the protection of other legitimate uses of groundwater (General Chemical Test). For Northern Ireland and the Republic of Ireland a single value of 37.5 mg/l (as NO_3) was used, for England and Wales the value was 42 mg/l and for Scotland 31 mg/l was used. In each case UKTAG guidance was followed and the methodology set out in Annex II of Paper 11b(i) applied (see Annex 1).

The difference in derived values reflects the availability of monitoring data and the range of environmental settings. The need to derive and apply a threshold value as opposed to using the Groundwater Quality Standard defined in the Groundwater Directive (2006/118/EC) is also explained in the UKTAG paper.

It should be noted that the exceedance of a threshold value does not on its own result in a groundwater body being classified at 'Poor Status'. It triggers 'further investigation' to assess whether pollution is of significant magnitude to prevent the groundwater body achieving the relevant good status environmental objectives.

Development of the typology-based approach

Following a workshop organised by the Groundwater Task Team, a typology matrix was developed to identify a number of different hydrogeological/environments settings. For each of these settings nitrate behaviour in the sub-surface would be expected to be different. If these differences were significant, then different threshold values may be appropriate to ensure that WFD objectives could

[1] UKTAG guidance – Paper 11b(i): Groundwater Chemical Classification for the purposes of the Water Framework Directive and the Groundwater Daughter Directive.

be met. To keep the approach relatively simple to apply, the number of cells (typologies) in the matrix was kept to a minimum. The matrix is shown in Figure 1.

		Karst /	Porous/Dua Poros ty	Geoche Denitrifi Poter
Confine		1	1	1
Low K	Wet	1	1	1
	Cla Subsoil	1	1	1
Free Draining	>3m High - Moderate K	5	3	2
	<3m	6	4	2

Figure 1. Typology matrix for deriving thresholds values for nitrate

The matrix differentiates the broad range of hydrogeological characteristics of groundwater bodies and their susceptibility to pollution by nitrate. The matrix and its attributes also take into account some of the relevant parameters used in groundwater body characterisation and WISE reporting. The resulting matrix contains 15 cells representing the different combinations of settings. Because of the limited monitoring data currently available and the variation in, and availability of, environmental data across the UK and Ireland to populate the matrix, a further simplification was made by grouping some of the cells to form 6 main typologies (Figure 1).

In general nitrate concentrations in groundwater are expected to vary more in the typologies with a higher matrix score. Using the threshold derivation approach in UKTAG guidance this will result in the values being lower in the higher numbered matrix typologies (e.g. Type 6) because the difference between the 95th-percentile and the mean would be greater to account for the greater variability (scatter) in the data expected.

Application and testing of the typology

The matrix was tested by each country using the data and information available to them and the results combined to provide an overview of the range of threshold values.

As an example, the following approach was used in England and Wales. The different aquifer types were differentiated using the aquifer response and dominant flow mechanism characteristics derived from the BGS aquifer properties dataset. The different combinations of properties were grouped and mapped to the closest categories of the matrix in Table 1 – karst, porous/dual porosity and very slow flow (geochemical denitrification potential). The soil characteristics were determined by using the soil leaching potential dataset from the Environment Agency's Groundwater Vulnerability (GWV) Maps and derived from the NSRI National Soils Map. Low permeability (k) soils were mapped to the low leaching potential class on the GWV maps, high to moderate permeability thick soils to moderate leaching potential and high permeability, shallow free-draining soils to high leaching potential. GIS analysis was carried out to identify the location of each monitoring point, its hydrogeological/environmental setting and typology. Monitoring sites were grouped on the basis of their typology and an analysis of the data for each typology carried out to derive a threshold value using the UKTAG methodology of comparing the 95th percentile to the mean. The results are shown in Table 2.

GWTT Typology	Calculated Threshold Value (mg/l)	No of sample points
Class 1	40	411
Class 2	38	207
Class 3	37	104
Class 4	40	168
Class 5	39	354
Class 6	40	404
ALL data	**39.5**	**1663**

Table 2 Threshold values for England and Wales calculated using GWTT Typology.

A similar approach was applied in Scotland and Ireland using available information to subdivide the groundwater monitoring data into typologies and then derive a threshold value for each typology. Once this was complete the data from all countries was combined to determine threshold values for each typology across the UK and Ireland. The results are shown in Table 3.

Typology	**Description**	**Threshold Value**	**Number of monitoring points[2]**
1	All Flow Typologies with confined, low permeability, wet soil conditions	39	561
2	Slow Flow (PP)/Denitrification with medium to high permeability subsoil conditions	30	259
3	Mod Flow (Gravel/Fractured) with medium to high permeability soil & subsoil, 3m+ subsoil thickness	37	132

[2] Number of monitoring points that could be attributed to one of the typology classes and with sufficient data

4	Mod Flow (Gravel/Fractured) with medium to high permeability soil & subsoil, <3m subsoil thickness	36	240
5	Fast Flow (Karst) with medium to high permeability soil & subsoil, 3m+ subsoil thickness	39	373
6	Fast Flow (Karst) with medium to high permeability soil &subsoil, <3m subsoil thickness	36	500

Table 3. Typology Summary Results – UK and Republic of Ireland.

Potential threshold values ranged from 30 – 39 mg/l, but if Typology 2 is excluded the range is only 36-39 mg/l. As was stated earlier, the analysis was expected to show a pattern of increasing threshold value with typology class as a response to the expected increasing variability in groundwater concentrations in each of the environmental settings. This pattern was not observed in the results and overall the typology approach applied in this way shows very little difference between values derived for each class, with the exception of Type 2.

A further assessment was carried out on the England and Wales data to evaluate whether further differentiation using the geological setting would make a difference. The data were processed to differentiate between four main aquifer types (Chalk, Sherwood Sandstone, Carboniferous Limestone, Magnesian Limestone) and threshold values calculated. For each type threshold values were also calculated for the different soil permeability/thickness conditions.

The results again showed that there was very little difference between aquifer types and although there was a wider range when soil conditions were taken into account there was no consistent pattern in the results.

One final assessment was made after removing the monitoring data with low nitrate concentrations. As well as being a pollutant, nitrate also occurs naturally in groundwater with natural concentration of up to 10 mg/l (as NO_3). A recalculation of threshold values was carried out after excluding monitoring data with mean concentrations below 10 mg/l to determine whether this had any effect on calculated values. This made very little difference to the calculated threshold values.

Summary

Following a number of queries about the differences in nitrate threshold values being used across the UK and Ireland, the UKTAG Groundwater Task Team have re-assessed the methodology applied (cf UKTAG guidance). As a result a typology-based approach was developed and tested using data from across the UK and Ireland. The typology differentiated a number of hydrogeological/ environmental settings in which nitrate behaviour in groundwater would be expected to be different and hence different threshold values may apply.

The typology approach was applied individually by each country using groundwater monitoring results for the period 2003/2008 (6 years) and other environmental data to differentiate between the different typology classes. A review of the outcomes of this work showed that there was little difference in the calculated threshold value for each typology class, and that the expected decrease in value with class number was not observed.

Further analysis of the data was carried out to look at the importance of (hydro)geological control on the derivation of threshold values. This involved examining the data from four of the main aquifer types across the UK. This analysis also considered the potential effects of including/excluding groundwater data with no obvious anthropogenic nitrate impact. The results again showed no significant difference between the aquifer types and typology classes.

Although further analysis could be carried to test the sensitivity of the typology approach and consider different ways of combining data to derive the typology classes, it is concluded that this is unlikely to improve the reliability and confidence in applying a typology-based approach to deriving threshold values at this time.

Conclusions

1. The investigated typology-based system results in generally only small differences (range) in nitrate threshold values. For five of the six typologies values range from 36-39 mg/l (as NO_3) with the sixth at 30 mg/l. Also, the distribution of values is not as expected suggesting that the hydrogeological and environmental conditions considered are not able to differentiate nitrate behaviour in the sub-surface.

2. A number of possible options for setting threshold values can be considered:

    a. Undertake further development of the typology based approach to take account of other environmental factors;

    b. Apply UKTAG Guidance 11b(i) Annex II Option 1 and Option 2, and continue to use TVs derived during first river basin planning cycle with the associated differences in value or;

    c. Apply UKTAG Guidance 11b(i) Annex II Option 2 only and establish a single threshold value of 37.5 mg/l (as NO_3) - 75% of Drinking Water Standard and Groundwater Quality Standard.

3. Having considered the options, GWTT recommends, for consistency across the UK, that a threshold value of 37.5 mg/l (as NO_3) is adopted for the second river basin planning cycle. GWTT believes that this is the most proportionate way of balancing the need for a single threshold value with the way in which it will be applied in the Drinking Water Protected Area Test and the General Chemical Test.

4. The effect of any change should be minimal as the exceedance of the threshold value does not on its own result in a groundwater body being classified at 'Poor Status'. It triggers 'further investigation' to assess whether pollution is of significant magnitude to prevent the groundwater body achieving its environmental objectives. One component of this further investigation would be to identify if any individual groundwater samples from the operational monitoring programme shows an exceedance of the Groundwater Quality Standard of 50 mg/l (as NO_3).

5. UKTAG Paper 11b(i) should be amended to take into account these changes. This would include the amendment of Annex I (Threshold Values and Lists of Indicator Determinands) and the removal of Annex II.

Annex 1

Extract (Annex II) from UKTAG Paper 11b(i), version 21.2 (after peer review, 20/06/07) which was used for groundwater body classification during the first cycle of river basin management planning.

Thresholds for the Groundwater Classification Tests - The Use of Mean and 95th Percentile Values.

Introduction

This Annex explains the principles for assigning groundwater classification threshold values for:

- the Drinking Water Protected Area Test;
- the General Assessment of Quality Test.

Drinking Water Protected Area Test

Drinking water standards are expressed as maximum acceptable concentrations in the Drinking Water Directive and should be compared to peak concentrations found in groundwater. However, we cannot assume that monitoring data will identify these peaks. Threshold values are needed for this test that are related to peak concentrations measured in abstracted water.

A 95th percentile is routinely used in compliance assessment for surface water quality standards in UKTAG guidance, even though the standard is referred to as an 'Absolute Limit'. This is because the use of 95th percentile allows confidence of failure to be calculated.

Normally, groundwater quality data are collected less frequently than for rivers (see UKTAG monitoring guidance). As a result, our ability to routinely use the 95th percentile as the threshold for groundwater assessment is constrained because the 95th percentile cannot be calculated with any degree of reliability. This is due not only to sparsity of data but also to the variability in groundwater concentrations in different hydrogeological settings and measurements that are below the level of detection for some parameters.

If the 95th percentile cannot be used, we need an alternative. This should establish a threshold value against which the monitoring data can be compared with adequate confidence. The outcome should, as far as possible, be equivalent to using a 95th percentile.

Work carried out for designation of Nitrate Vulnerable Zones in England and Wales concluded that well over 50% of monitoring sites have insufficient records to reliably estimate anything other than the mean concentration. Given that nitrate is the parameter for which we have most groundwater quality data, the situation will be even worse for other determinands. As a consequence, groundwater thresholds should be set as values against which mean concentrations (or other relevant parameter value) can be compared. However, in setting the threshold it is important to ensure that the risk of misclassification is kept as low as possible.

The following approach is recommended for setting threshold values for groundwater chemical status assessment:

1. Where there are sufficient reliable monitoring data for each individual site (adequate frequency/time series) and non-detects are infrequent, calculate 95th percentile values along with confidence intervals. Compare these directly with the DWS or other relevant standard, as appropriate.

   <u>NOTE</u>: Taking into account the earlier discussion, we are unable to apply this approach in the first river basin cycle.

2. Where data are insufficient to calculate 95th percentiles for individual sites, compare the mean concentration (or relevant parameter value) of the monitoring data at a site against the threshold value. This threshold must be set so that, if it is not exceeded by the mean of a dataset, there is a reasonable expectation that the 95th percentile would not exceed the Maximum Admissible Concentration, if those 95th percentiles could be calculated.

   Calculate the threshold value as follows:

   - **Option 1**: where there are sufficient data, examine the difference between the mean value and the 95th percentile value (and associated confidence limits, where appropriate) for **<u>all</u>** monitoring sites. Calculate the threshold value by subtracting the average difference between the mean values and the 95th percentile values (or lower confidence limit, if appropriate) from the relevant standard. This calculated threshold can be expressed either as an absolute value or as a percentage of the relevant standard.

     Note: although there are insufficient data to calculate 95th percentile values for individual sites, we are able to <u>estimate</u> a 95th percentile from sparse data. For this we need to make an assumption about the shape of the underlying distribution based on the behaviour of larger data sets from other supposedly similar sites. This is an *approximation* rather than a 'robust' approach. It means that we can <u>estimate</u> the average difference between the mean and the 95th percentile (or lower confidence limit if appropriate) for the whole population of data. For example, Figure 1 shows the relationship of the mean and the 95th percentile for a selection of nitrate data from England and Wales. The dotted line of best fit indicates that if the mean is used, then the threshold value would be set at 37 mg/l, compared to 50 mg/l if the 95th percentile was to be used. Note that the data and derived threshold value are for illustrative purposes only and there is no statistical or hydrogeological basis to assume the same numeric relationship will apply for other substances or even nitrate in either Scotland or Ireland.

     Option 2 : Where there are insufficient data (for a particular region or substance) to estimate a 95th percentile for individual or groups of sites, assign a default threshold value that is lower than the relevant standard and compare against the mean concentration (or parameter value). Without the benefit of statistics, this can only be assigned using best judgement. On this basis it is proposed that, the threshold should be set at a value of 75% of the relevant standard (Maximum Admissible Concentration). This value has been selected taking into account the large variability in hydrogeological settings, potential temporal variability in parameter values and because it introduces what is believed to be an adequate degree of protection such that the risk of misclassification is acceptable. If applied to individual pesticides, this would lead to a threshold value of 0.075 μg/l.

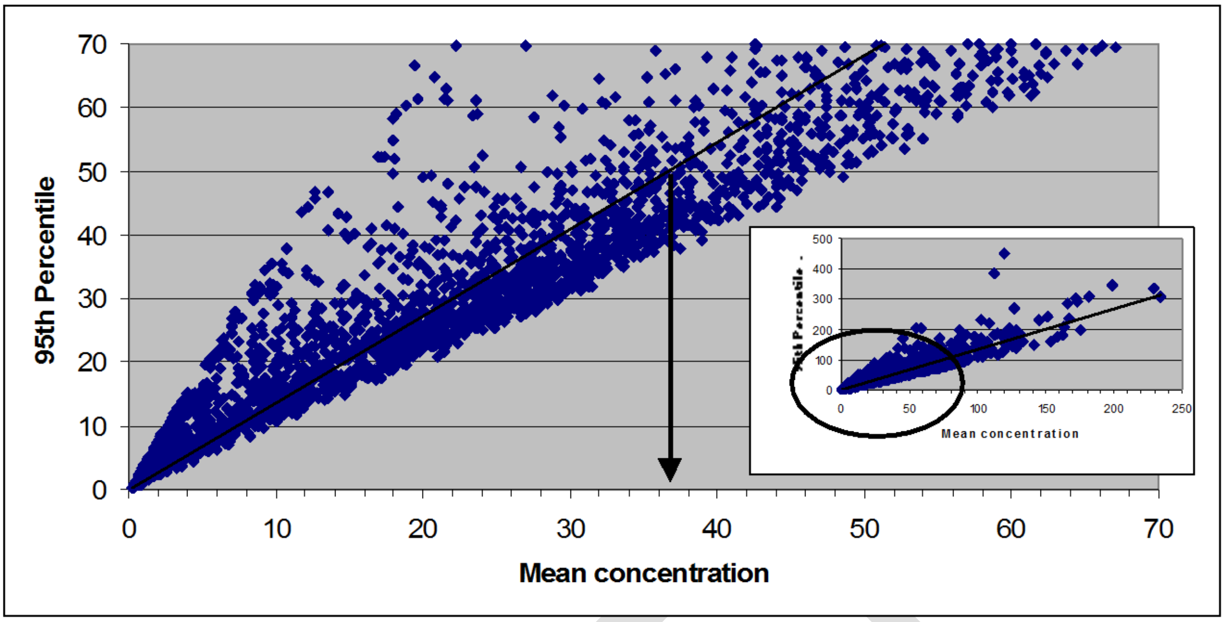

Figure A1. **Comparison of mean nitrate concentrations and the 95th percentile for selected groundwaters in England and Wales.**

General Assessment of Quality Test: Rationale

This test requires us to examine the extent of impact of one or more pollutants on a groundwater body. The GWDD requires us to set thresholds for pollutants that are relevant to this body-wide assessment. It also defines thresholds/standards for nitrates and pesticides and requires Member States to set values for other pollutants as necessary. However, the GWDD does not prescribe whether these standards relate to Maximum Admissible Concentrations, mean parameter values or some other measure.

In order to ensure consistency between Nitrates Directive and the WFD/GWDD, it is considered that the standards prescribed should relate to 95th percentiles. As a result the same issues that apply to Drinking Water Protected Areas (DWPA) apply here and it is proposed that the same principles for assigning thresholds should be used.

One difference is noted: the General Assessment of Quality Test requires the aggregation of data from a number of sites within a groundwater body or group of bodies. UKTAG guidance 12a examines the most appropriate method for addressing this issue and has concluded that comparing the threshold against an appropriate aggregation of the means from appropriate sites is the correct approach. Where data are aggregated in this way, 95th percentiles cannot be calculated and so the direct use of 95th percentiles, as described in the DWPA section (where the assessment relates to individual points) is not possible. Further guidance is presented in the main body of this paper.