Expert judgement on the underpinning of the assessment threshold used in project-specific calculations of nitrogen depositions

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Summary

When using a model for a specific (policy) goal, it must first be determined what the scientific application range of a model is. The application range indicates where the model can be used to make reliable statements (given the purpose for which the calculation results are used). If the results are too uncertain (there is a 'false certainty'), then the model is insufficiently reliable (not valid) for use. There is always a limit to a model. In the context of deposition modelling of individual sources, the scientifically accepted limit below which results are insufficiently reliable lies between approximately 1 and 35 mol/ha/year. Calculation results lower than 1–35 mol/ha/year are scientifically insufficiently reliable for use in decision-making (the model system is then not fit for purpose). Theoretical and empirical considerations, the agreement with other models and peer consensus do not allow room for policy – due to false certainty – to scientifically calculate nitrogen depositions from individual sources and to attribute effects where the deposition is lower than 1–35 mol/ha/year. The current assessment threshold in the Netherlands of 0.005 mol/ha/year cannot therefore be maintained from a scientific, legal and policy perspective; the new assessment threshold to be chosen should be at least 200 times higher. Which assessment threshold between 1 and 35 mol/ha/year is ultimately chosen is not up to science, because no clear answer can be given, and non-scientific factors such as the precautionary principle also play a role. How this precautionary principle is implemented is not a question that can be answered by science. However, the room for policy here is constrained by the scientifically substantiated range of 1–35 mol/ha/year. In Germany, an assessment threshold of 21 mol/ha/year (more than 4,000 times higher than the current assessment threshold in the Netherlands) was chosen based on the precautionary principle. The Netherlands could follow this approach, but from a scientific point of view, higher or lower assessment thresholds are also possible (provided they are chosen within the substantiated range).

Introduction

I have been asked for an independent expert judgement on the way in which the assessment threshold of 0.005 mol/ha/year has been substantiated in project-specific calculations of nitrogen depositions.[1] First of all, I must state that although my broad scientific background also includes boundary layer meteorology, atmospheric chemistry and

[1] This independent expert judgement on the substantiation of the assessment threshold was written on behalf of De Nieuwe Denktank and is a variation on an earlier independent expert judgement (Petersen 2022), which was written on behalf of the Ministry of Infrastructure and Water Management on the substantiation of the maximum calculation distance. The current expert judgement is analogous to my previous expert judgement (and section 1 is largely identical) – after all, the reasoning is the same: scientifically, legally and policy-wise, there is no policy room in this file for calculating with false certainty.

(large-scale) dispersion modelling, the requested expertise on my part here is mainly on methodology of science.[2] Naturally, my background in natural sciences does help with the substantive assessment of the discussion on the assessment threshold.

In my expert judgement on the underpinning on of the assessment threshold in project-specific calculations of nitrogen depositions, I will, as transparently as possible:

1. Reflect on the importance of delineating the application range of scientific models, especially when they are used in decision-making. I place this in the context of dealing responsibly with uncertainties as codified in the Guidance for Uncertainty Assessment and Communication.
2. Judge on the underpinning of using an assessment threshold of 0.005 mol/ha/year in project-specific calculations of nitrogen depositions.
3. Respond (briefly) to the points about 'cumulation' and 'precaution' raised by the Hordijk Committee and TNO, in the light of 1 and 2.

1. Guidance for Uncertainty Assessment and Communication: Scope of application of scientific models

A good starting point for the discussion on how to deal with uncertainty at the interface between science and decision-making (in the context of policy-making or licensing – and with a focus on the scope of application of scientific models) can be found in the *Guidance for Uncertainty Assessment and Communication*, originally published in 2003 (Petersen et al. 2003; Janssen et al. 2003; Petersen et al. 2013) and in the report *Dealing with Uncertainty in Policymaking* (Mathijssen et al. [2007] 2008). These documents represent the state-of-the-art in dealing with uncertainties in science and policy. The Guidance for Uncertainty Assessment and Communication has been developed for use by scientists in the environmental domain,[3] in the Netherlands and abroad.[4] The Group of Chief Scientific Advisors of the European Commission's Scientific Advice Mechanism has explicitly recommended the Guidance approach for wide use in decision-making based on scientific input (European Commission 2019, 46–49).

The scientist-focused Guidance for Uncertainty Assessment and Communication pays particular attention to the following six key points:

1. How is the problem framed; which contextual factors are included/excluded?
2. What are the main parties (stakeholders/ actors) involved; what are their views, roles, stakes and involvement with respect to the problem, and what would be the added value of involving certain stakeholders in the study?
3. What are the main indicators/visualisations used in this study and how do these relate to the problem definition?
4. How adequate is the knowledge base that is available for the study?

[2] I have had no involvement in my career with the development of the models under discussion here (mainly because these models are not managed by the PBL Netherlands Environmental Assessment Agency).
[3] The Guidance for Uncertainty Assessment and Communication can be applied more broadly than just in the environmental domain.
[4] The first phase of development took place at the RIVM and further development took place later at the PBL.

5. What are the uncertainties relevant to this problem and what is their nature and location?
6. How is uncertainty information communicated?

All these points are important for scientists who develop models in the context of policy-making or licensing and make calculations with their models in order to reach reliable statements based on these models.[5] There is no general 'guidance' available for policy-makers and other decision-makers, although there is a need for one:

> Policymakers are faced with a dilemma: on the one hand, they are expected to base their decisions on clear, measurable facts, while, on the other hand, they are confronted with developments that give rise to uncertainties as a result of variable and unpredictable processes. (Mathijssen et al. [2007] 2008, 9)
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> The exchange of experiences and best practices [in the conference 'Dealing with Uncertainty in Policymaking' of 16 and 17 May 2006] was expected to provide some guidance for dealing with uncertainty in policymaking. It turned out that we were aiming too high, because of the complexity of the issues involved and the great diversity in policy environments, policy questions, types of uncertainty and experiences. (Don [2007] 2008, 5)

Of course, the complexity of decision-making does not absolve decision-makers and other parties involved from the duty to ascertain, in particular, the scope of application of the models used. They should encourage scientists to deal responsibly with uncertainty in the context of decision-making. One of those responsibilities is not basing decisions or having them based on results that are too uncertain according to the scientists involved (where that limit lies is exactly what the discussion is about, see the next section).

There are several examples of scientists and consultants who have contributed to dealing irresponsibly with uncertainties, for example by offering quasi-certainties ('false certainties'), quantifying non-quantifiable uncertainties, providing point estimates instead of ranges, believing in their own models and analyses and applying knowledge outside the range of phenomena for which it has been validated (Petersen and Van Asselt [2007] 2008, 64). From a scientific point of view, this needs to change.

The Guidance for Uncertainty Assessment and Communication is intended as an 'antidote' to this tendency of many scientists (which, incidentally, they mainly give in to under pressure from decision-makers)[6] and thus forms the basis for carefully dealing with uncertainties in decision-oriented scientific research (Petersen et al. 2013, 6). It is not only important for scientific research itself to know where uncertainties are located (in model studies, for example, in the 'model structure', the 'model parameters', the 'model inputs' or the 'technical model', see table 1). At the interface between science and decision-making, this then mainly concerns assessing the impact of uncertainties on specific model results

[5] 'Reliability' has three dimensions: (1) statistical reliability ('confidence intervals'), (2) methodological reliability, and (3) public reliability (Smith and Petersen 2014, 142–47). Each of these three dimensions plays a role in public discussions about 'the' reliability of models for policy-making or licensing. I will discuss methodological reliability in more detail below.

[6] Fear of being held responsible for something can also play a role. However, scientists have a social responsibility to monitor what is done with their results, to advise on this and to warn against misuse.

UNCERTAINTY MATRIX			Level of uncertainty *(from determinism, through probability and possibility, to ignorance)*			Nature of uncertainty		Qualification of knowledge base (backing)			Value-ladenness of choices		
Location ↓			Statistical uncertainty (range+ chance)	Scenario uncertainty (range as 'what-if' option)	Recognized ignorance	Knowledge-related uncertainty	Variability-related uncertainty	Weak –	Fair 0	Strong +	Small –	Medium 0	Large +
Context		Ecological, technological, economic, social and political representation											
Expert judgement		Narratives; storylines; advices											
Model	Model structure	Relations											
Model	Technical model	Software & hardware implementation											
Model	Model parameters												
Model	Model inputs	Input data; driving forces; input scenarios											
Data (in general sense)		Measurements; monitoring data; survey data											
Outputs		Indicators; statements											

Table 1. Uncertainty matrix (Janssen et al. 2003, 16; Petersen [2007] 2008, 17; Petersen et al. 2013, 27). See Petersen et al. (2013, 29–32) for a concise explanation of all dimensions in the uncertainty matrix and Petersen ([2006] 2012) for a philosophical discussion.

and conclusions based thereon (including on the scope of application of the models in the specific decision-making context). And that is why it is important to have an idea of the reliability of a model *for a certain purpose* (see also Smith and Petersen 2014, 137). And even before that: 'When building the model, it is important when selecting model components to take into account the policy-related requirements and the circumstances of the specific policy problem' (Hordijk [2007] 2008, 54).

In Guidance terminology, the assessment of the methodological reliability of a scientific model involves giving a 'qualification of the knowledge base (backing)' (see table 1). This concerns 'the degree of underpinning of the established results and statements' (Petersen et al. 2013, 31). If the qualitative classification 'weak' is given, then this is an indication 'that the statement of concern is surrounded by much (knowledge-related) uncertainty, and deserves further attention' (Petersen et al. 2013, 31).[7] To determine the qualification of the knowledge base, '[c]riteria such as empirical, theoretical or methodological underpinning, and acceptance/support within and outside the peer community may be used' (Petersen et al. 2014, 32). A so-called 'pedigree analysis' can be used for this:

> Pedigree analysis is an analysis that evaluates the 'strength' or scientific status of a figure [number, ap]. Pedigree literally means 'genealogy', 'origin' or 'background': how did the figure originate and does it have a good background? Two aspects are considered here: how does a figure (in a conclusion) come about and what is its scientific status, and how is it substantiated?

[7] The Guidance emphasises that the qualification of the knowledge base is always given in the context of the purpose of using the knowledge and therefore never about a model detached from the context.

> Criteria that may be used in the pedigree analysis for evaluating a model include ‘proxy’ (degree of directness of the indicator applied), ‘quality and quantity of empirical basis’, ‘theoretical basis’, ‘representation of the system’s underlying causal mechanisms’, ‘plausibility’ and ‘degree of consensus’. (van der Sluijs [2007] 2008, 25–26)

Pragmatic choices also play a role in determining whether a model is ‘good enough’ for a particular purpose (for example, the budget and time available must be used efficiently). In terms of the ‘uncertainty matrix’ this can be seen as one of the dimensions of the value-ladenness of choices regarding the model.[8]

A false sense of certainty quickly arises in the case of model calculations of nitrogen deposition resulting from individual projects. In the remainder of this expert judgement, I will focus on the main question at hand, namely whether the calculation of nitrogen deposition with an assessment threshold of 0.005 mol/ha/year in the context of granting licenses for individual projects leads to false certainty and is not fit for purpose.

2. Judgement on the underpinning of using an assessment threshold of 0.005 mol/ha/year for project-specific calculations of nitrogen depositions

The Hordijk Committee (the Advisory Committee on Measuring and Calculating Nitrogen) published its final report on 15 June 2020 (*Measure More, Calculate More Robustly*). The summary discusses the reliability of high-resolution deposition modelling in more detail and the committee indicates

> that the calculation tool AERIUS Calculator is not fit for purpose. There are two reasons for this: 1. the imbalance between the detail required by policy and the degree of scientific uncertainty in calculating the deposition on a small area and 2. the unequal treatment of different sectors due to the use of different models (SRM- 2, OPS) when granting a license. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 4)

This is further specified in the conclusions of the report:

> Two considerations play a role in the assessment of AERIUS calculations for licensing. In the first place, the reliability of the prediction is insufficient due to the use of a very low assessment threshold, and this approach leads to false certainty. AERIUS Calculator (hereinafter referred to as AERIUS for short) calculates small contributions to concentrations and deposition based on emissions from a project. The uncertainty of this extra deposition on Natura 2000 areas is many times higher than the assessment threshold at the spatial scale used (hexagons the size of one hectare). Science cannot provide what policy demands here.
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> A second consideration is that it is indefensible that a different calculation system (SRM-2) is used in AERIUS when granting licenses for the construction of a road than for the construction of a stable (OPS), whereby also the deposition of nitrogen oxides at more than five km from the source is not included. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 9)

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[8] The following dimensions of ‘value-ladenness of choices' can be distinguished: general epistemic values, discipline-bound epistemic values, sociopolitical values and practical values (Petersen 2006, 50; 2012, 51).

One way that the Hordijk Committee advised to make the models more suitable for the granting of licenses, namely to calculate the deposition not on a hexagon but on a cluster of hexagons, classified according to habitat type – which would reduce the false certainty in deposition calculations at a great distance from the source – has not been followed by the government. However, the government has opted for a different method in 2021 – using a uniform maximum calculation distance (of 25 km, i.e., five times greater than the 5 km previously used for road traffic) – to make the models more fit for purpose use by not using unreliable calculations based on hexagon level beyond that calculation distance.[9] Using a maximum calculation distance, while still calculating at the hexagon level within 25 km, solves part of the problem of false certainty. But the problem of false certainty linked to the use of an assessment threshold of 0.005 mol/ha/year has not yet been solved. I share the opinion of the Hordijk Committee on this point that the current system is not fit for purpose. The assessment threshold of 0.005 mol/ha/year concerns a pragmatic, computer-technical choice made by RIVM experts that does not have any substantive scientific meaning.

Below, I will discuss in more detail the justification provided by TNO for delineating the application range of the model used for project-specific calculations by the use of a much higher assessment threshold (in the light of what is said in science about methodological reliability and what has been crystallised about this in the Guidance for Uncertainty Assessment and Communication). But first the possible deliberate use of false certainty in the context of the precautionary principle must be considered, which is scientifically undesirable (see also section 3). The Hordijk Committee sheds light on this issue as follows for the choice of the assessment threshold ('threshold value') of 0.005 mol/ha/year:

> For the time being, the precautionary principle calls for a strict threshold value when granting licenses. An ambitious source policy with established national objectives has the advantage that the threshold values could be increased when granting licenses, so that the uncertainties in the calculations for the licenses become less critical and false certainty becomes less prominent. (Advisory Committee on Measuring and Calculating Nitrogen 2020b, 10)

A tension in the quote above is that limiting false certainties – for example, by increasing the assessment threshold value – is scientifically preferred by far. The fact that this limitation, which is necessary from a scientific point of view, does not always happen (and that calculations are still based on false certainties) has to do, among other things, with the value-laden nature of the choices made by the experts.[10] Modellers can choose to accept false certainties based on an assumption (which is not always factually correct in terms of the effect)[11] that this is necessary because of a 'precautionary principle'. Here, however, epistemic and non-epistemic values mix in a non-transparent manner in the systematics of the model and from a scientific point of view it is preferable to let epistemic values prevail in the assessment of models' fitness for purpose.

[9] Both ways of making the models more fit for purpose are not mutually exclusive and can be combined (i.e., calculations with clusters of hexagons within the maximum calculation distance).
[10] See the uncertainty matrix (in table 1) and footnote 8.
[11] Decisions made on the basis of false certainties need not have the (negative or positive) effect that is modelled.

In scientific practice there are standards for determining the reliability of knowledge. In the Guidance for Uncertainty Assessment and Communication, these standards have been crystallised into the various dimensions that are (in parallel) important in determining the qualification of the knowledge base (see the previous section). The dimensions of methodological reliability can be grouped as follows: (i) the theoretical basis, (ii) the empirical basis, iii) the agreement between different models and (iv) peer consensus (Petersen 2006, 57–62; 2012, 58–62). Following the TNO (2022) report, the scientific substantiation of an assessment threshold of 0.005 mol/ha/year versus an assessment threshold of 1–35 mol/ha/year can be briefly summarised along these four dimensions:

- *Theoretical basis:* The assessment threshold of 0.005 mol/ha/year has no basis in any scientific theory. From a scientific point of view, it is theoretically relevant to derive the assessment threshold from physical, chemical and biological considerations.
- *Empirical basis:* The assessment threshold of 0.005 mol/ha/year has no empirical basis. Comparison between calculated and measured concentrations of substances in a validation experiment for a single source produces a 'noise' in the calculated deposition of 6–12 mol/ha/year. The smallest measurable quantities of NO_x and NH_3 (0.4 and 0.1 µg/m^3 respectively) provide an estimate of the smallest nitrogen deposition that can be determined of 35 mol/ha/year. A 'noise level' can also be derived from the accuracy with which critical loads values are given (0.1 kg/ha/year); deposition values smaller than this 0.1 kg or 7 mol/ha/year fall within this noise.
- *Agreement between different (versions of) models:* The assessment threshold of 0.005 mol/ha/year is not used in foreign models (see under 'peer consensus' what is used abroad). The 'noise' in total background deposition can be determined using different versions of the AERIUS model instrument. The use of different basic data for meteorology land use leads to noise between 1 and 10 mol/ha/year.
- *Peer consensus:* All experts involved agree that the assessment threshold of 0.005 mol/ha/year is not a scientifically based assessment threshold. This also applies to the experts in the Hordijk Committee and at TNO. Furthermore, TNO (2022) shows the judgements of foreign experts: in the United Kingdom an assessment threshold of 1% of the critical loads is used (with a variation of the critical loads between approximately 500 and 2,000 mol/ha/year, this assessment threshold is therefore between 5 and 20 mol/ha/year), in Flanders an assessment threshold of 21 mol/ha/year was used, in Denmark deposition is rounded to whole kg/ha/year (below 0.5 kg/ha/year or 35 mol/ha/year is therefore rounded to zero) and in Germany the threshold value has been determined on the basis of the smallest measurable quantities of NO_x and NH_3 (corresponding to a nitrogen deposition of 35 mol/ha/year – as a precaution the threshold value has been set at 21 mol/ha/year, see Balla et al. 2014).

Given the information available about uncertainties in deposition modelling, I consider the scientific underpinning of an assessment threshold of 0.005 mol/ha/year to be insufficient (because it is absent). Scientifically speaking, the assessment threshold should be between 1 and 35 mol/ha/year. In my opinion, the current model instrument, which uses an assessment threshold that is at least 200 times too low, is not fit for purpose.

Which assessment threshold between 1 and 35 mol/ha/year is ultimately chosen is not up to science, because no clear answer can be given, and non-scientific factors such as the precautionary principle also play a role. How this precautionary principle is implemented is not a question that can be answered by science. However, the room for policy here is constrained by the scientifically substantiated range of 1–35 mol/ha/year, because an assessment threshold outside this range cannot be scientifically justified based on the above dimensions. In Germany, an assessment threshold of 21 mol/ha/year (more than 4,000 times higher than the current assessment threshold in the Netherlands) was chosen based on the precautionary principle. The Netherlands could follow this approach, but from a scientific point of view, higher or lower assessment thresholds are also possible (provided they are chosen within the substantiated range).

3. Response to Hordijk Committee and TNO on point about 'cumulation' and 'precaution'

In light of the above, I provide a brief response to some relevant points made by the Hordijk Committee and TNO about 'cumulation' (the addition of many small sources below the threshold value to an effect that together can be a significant effect) and – in connection with this – 'precaution':

Hordijk Committee: 'The uncertainty in the calculation is much higher than the threshold value that has been set. Nevertheless, this practice is necessary for application in policy, to prevent many small additional emissions from adding up to a large increase in deposition. An assessment threshold based on model uncertainties at a local scale is not workable for policy applications' (Advisory Committee on Measuring and Calculating Nitrogen 2020, 14). And, as already quoted in section 2: 'The precautionary principle calls for a strict threshold value when granting licenses. An ambitious source policy with established national objectives has the advantage that the threshold values could be increased when granting licenses, so that the uncertainties in the calculations for the licenses become less critical and false certainty becomes less prominent' (Advisory Committee on Measuring and Calculating Nitrogen 2020, 10) .

TNO: It is questionable whether the effect of cumulation may play a role when choosing a scientifically sound, higher threshold value: 'The contributions of all projects to the deposition below the calculation limit are added to the background. Their contribution is therefore not removed from the estimate but is included in the background' (TNO 2022, 23). However, according to TNO, scientific considerations can be deviated from when determining a threshold value: 'Of course, the precautionary principle can give rise to a policy choice for a lower value' (TNO 2022, 28).

Response: As described in the previous section, theoretical and empirical considerations, agreement with other models and peer consensus do not allow room for policy – due to false certainty – to scientifically calculate nitrogen depositions from individual sources and to attribute effects where the deposition is lower than 1–35 mol/ha/year. Trying to prevent 'cumulation' of low depositions as a 'precautionary measure' cannot be scientifically substantiated in the context of evaluating the effects of an individual project – after all, no effect can be attributed to that individual project. There is no room for policy to set the assessment threshold lower. The problem of cumulation therefore legally requires a different solution. The Council of State was also completely clear about this in the ruling of 5 April 2023 *ECLI:NL:RVS: 2023:1299 (Route decision A12/A15)*: only the individual project contribution may be taken into account and no calculations with false certainty may be used by way of precaution. Managing the risk of cumulation is a governmental task through generic policy. In the ruling (under 1.5), the Council of State writes, for example: 'The question whether the competent administrative bodies implement the obligation to take conservation measures and appropriate measures in relation to the total deposition contribution to a Natura 2000 area in a timely manner and with the correct measures is, in the opinion of the Administrative Jurisdiction Division, not relevant in a decision granting a license for a plan or project.' This argumentation applies both to false certainty due to calculations beyond a maximum calculation distance and to false certainty due to calculations using an assessment threshold that is scientifically too low.

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About the author

Arthur Petersen (1970) studied physics (VU Amsterdam, 1993) and philosophy (VU Amsterdam, 1995) and obtained his doctorates in atmospheric physics and chemistry (Utrecht University, 1999), science studies and philosophy of science (VU Amsterdam, 2006) and science and religion/philosophy of culture (Oxford, 2022). In 2001 he joined RIVM's Netherlands Environmental Assessment Agency (one of the predecessors of the PBL Netherlands Environmental Assessment Agency) and in 2003 became project leader of the Guidance for Uncertainty Assessment and Communication, which had been in development since 2001 (1st edition: RIVM/MNP 2003; 2nd edition: PBL 2013). From 2003–2014 he was Programme Leader Methodology and Modelling and from 2011–2014 he was PBL's first Chief Scientist; in the latter role he was a member of the Executive Board and responsible for scientific quality assurance. He was Professor (by special appointment) of Science and Environmental Public Policy at the VU (appointed by the PBL) from 2011–2016. In 2014 he switched to a full-time Professorship: he became Professor of Science, Technology and Public

Policy at University College London (UCL). Since 2000 he has been involved in the Intergovernmental Panel on Climate Change (IPCC) – until 2014 from the Dutch delegation, then from the UCL delegation (an 'observer organization'). In 2019 he was elected a member of Academia Europaea, the European Academy of Sciences. He regularly carries out independent research, advice and evaluation assignments for governments and knowledge institutions (in the past year, among others for the Netherlands Delta Commissioner and the Netherlands Scientific Council for Government Policy). He lives in The Hague. For more information and publications see here (university's personal web page).