Input to the EU consultation for the evaluation of the Nitrates Directive:

A scientific response from a Dutch perspective

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Summary

The Nitrates Directive (ND) has come into force in 1991 with the objective to reduce nitrate losses from agricultural soils to protect ground- and surface water. Member states (MS) have to identify Nitrate Vulnerable Zones (NVZs), are obliged to monitor nitrate levels in ground- and surface waters and to set up National Action Programmes (NAPs) to reduce pollution from agricultural sources in NVZs including implementation of the limit of 170 kg nitrogen (N) per ha for animal manure.

During the first decades after initiation, the ND effectively reduced nitrate losses from agricultural soils with the strongest progress being made in areas with intensive agriculture. However, the objective of achieving good water quality in all aquatic water bodies throughout all MS has not been realized yet. The latest reporting for the EU shows that limit for nitrate is exceeded in 14% of the groundwater monitoring sites and that 36% of surface water bodies are yet classified as eutrophic (COM/2020/635).

This is a scientific response from a broad group of researchers in soil, plant, animal and social sciences. We would like to share our experience of the last decades to improve future legislation.

- **Focus on balanced fertilization for synthetic fertilizer and manure.** Nitrate leaching can be reduced by lowering N surpluses by applying principles of balanced fertilization and accounting for nitrogen release from soil. Any source of nitrogen, including manure and RENURE fertilizers, can be safely used within NVZs as long as nitrogen surpluses are within safe limits. This creates incentives for farmers to take measures to improve nutrient-use-efficiency.

- **From Nitrates to Nutrients Directive**. The ND should be extended towards a Nutrients Directive covering both nitrogen and phosphorus fertilization as both nutrients contribute to eutrophication of water bodies.

- **Local conditions should be leading in reaching** environmental targets. Target-based and site-specific measures are generally more effective in reducing nutrient losses as compared to generic measures.

- **Account for spatial and temporal variability**. Nitrate concentrations in groundwater depend on sampling depth and are variable in space and time. The ND is yet not clear on when targets are met. Trends in nitrate should be assessed over longer time scales to account for temporal variation.

- **Effective and proven legislation**. Implementation of effective and proven measures may increase acceptance of manure policy by farmers.

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Balanced N fertilization based total N inputs will effectively reduce nitrogen losses

The main objective of the ND is to reduce pollution of ground- and surface waters by nitrates from agricultural sources. Nitrate leaching is the overall result of multiple factors influenced by biochemical and soil physical processes. A simplified but robust indicator for nitrate leaching is the N surplus combined with a soil-specific leaching factor. Total N application rates should therefore be reduced in order to reduce N surpluses and nitrate leaching. Yet, the ND sets a limit for the use of N from livestock manure while there is no harmonisation on restrictions for the use of total N from synthetic and organic fertilizers.

There is no scientific evidence that underpins that a generic limit of 170 kg N/ha for nitrogen from livestock manure is effective in reducing nitrate leaching. In particular on grassland, higher N application rates for livestock manure are possible without inducing increased risks for nitrate leaching (de Boer et al., 2023; (Wei et al., 2021). This is also evident from the long-term monitoring of nitrate concentrations on Dutch derogation farms where on average 220 kg N from livestock was applied while nitrate concentrations were still below average values for arable land (Van Duijnen et al., 2023).

The distinction between N from synthetic fertilizer versus livestock manure is often justified by referring to the uncontrolled release of N from the organic fraction of livestock manure. However, field studies show that, in soils with a considerable N stock, release of N from the soil N stock is larger than the amount of N released through N mineralization from freshly applied livestock manure (Frick et al., 2022 (Glendining et al., 2001)). Hence, untimely N mineralization is a point of concern in all agricultural fields regardless of the source of the N fertilizer that has been used as also use of mineral N fertiliser contributes to the build-up of organic N stocks in soil (Goulding et al., 2006). Sowing catch crops is an effective measure to take up mineral N left after harvest of the main crop. Catch crops typically take up 20 to 70 kg N/ha (Van Geel et al., 2023).

Effective measures to reduce nitrate leaching are those that focus on reducing N surpluses (Hansen et al., 2017). Fertilization rates for total N shall be optimized to meet crop demand whilst taking into account the release of N from the soil organic N pool. For policy purposes, a simplified N-balance can be used assuming that the soil organic N stock is at steady e.g. assuming equilibrium between the annual N mineralization rate and the input of organic N from crop residues, catch crops and organic fertilizers. The N surplus is then defined as the difference between the total N inputs (N in mineral and organic fertilizers after correction for emissions during application, N-deposition, N-fixation) versus N output through crop harvest (Oenema et al., 2009).

Nitrogen balances are derived from total N inputs e.g. without distinguishing between N from manure and mineral fertilizers. A difference between livestock manure and synthetic fertilizers is however the lower fraction of effective N that becomes available for plant uptake within the first growing season. Effective nitrogen coefficients applied by member states for the calculation of total N fertiliser rates vary between 40-70% (Webb et al., 2009) which are typical values expressing the agronomic efficiencies e.g. the release within the first growing season after application. However, for environmental purposes, it is relevant to account for the multi-annual release of N as it is known that livestock slurries are nearly as effective as synthetic N when considered over longer time scales (Webb et al., 2009). Neglecting multi-annual release of N from animal manure by applying low coefficients for effective N means increases the risk for enhanced nitrate leaching on the longer term (Wei et al., 2021). Overall, livestock manure can be safely used in NVZs if application rates account for the long term release of N from manure. Instead of a limit for N from livestock manure, the ND shall focus on reducing total N inputs in NZVs and on harmonisation of the underpinning of N application rates.

Opportunities for target-based policy on dairy farms

Dairy farms in the Netherlands are highly productive. In terms of nutrient management, there are however large differences among dairy farms in terms of performance. The pilot project 'Cows and Opportunities' is a long-term project in which 15 commercial dairy farms, supported by scientists, and extension services work jointly on reducing nutrient losses. As part of this pilot, farmers are exempted from the generic application rate limits and can instead apply larger amounts of N from manure and/or mineral fertilizer if this is justified based on farm-scale nutrient balances. Standards based on N surplus appeared a strong incentive for farmers to improve their management in order to preserve water quality (Verloop et al., 2022). In general, setting operational targets for acceptable levels of nutrient losses stimulates farmers to apply measures that suit their farming system and local conditions. A target-based policy will give farmers in low risks areas some more flexibilities but stricter standards may be needed in polluted and leaching-sensitive areas.

Target-based policy on arable and vegetable farms

On arable farms, nitrate concentrations in the groundwater are higher than on dairy farms and often exceed the level of 50 mg/L (Fraters et al., 2020) which is partly due to the lower denitrification (the removal of nitrate from soil by transformation to dinitrogen gas under anaerobic conditions) rates in arable soils compared to grassland (Fraters et al., 2012). Nitrate leaching from arable soils can be reduced by strict nutrient management comprising a good balance of organic and mineral fertilizers, precision fertilization and the use of catch crops. In addition, adjusting crop rotations to include a larger share of low-leaching crops and introduction of new crop varieties with higher N uptake efficiencies will also attribute to better environmental conditions.

Most of the above mentioned measures are yet partly included in the Dutch NAP, but farmers experience them as restrictive. Instead, there is a strong wish for a target-based policy based on a maximum allowed N soil surplus instead of generic application rate limits and obliged cropping (plan) measures. The generic N application limits do no create an incentive to apply fertilizer based on crop demand. A consequence of a more target-based policy is however that efforts to meet goals will be different between farms depending on the local conditions such as, the location, soil type, or denitrification capacity of the soil. Hence, more efforts can be needed for farms on dry sandy soils that have a high risk of leaching or on soils in NVZs, while minor efforts might be sufficient soils that are less prone to N leaching.

Manure treatment and RENURE fertilisers

Large-scale manure processing plants primarily exist in regions with intensive livestock farming, such as Denmark, Flanders and the Netherlands. Disposal costs for liquid manure are a major cost item for manure treatment plants (Hermann et al., 2021). Technical developments in manure processing now enable production of fertilizer products that meet criteria of REnewable Nitrogen from livestock manURE (RENURE) products (Huygens et al., 2020) which reduces disposal costs once accepted.

Criteria for RENURE were derived by the Joint Research Centre (Huygens et al., 2020). They concluded that a fertilizer product from manure characterized by a ratio of total organic carbon (TOC) to total-N ≤ 3 or a mineral-N to total-N ratio ≥ 90% has a similar N leaching potential and agronomic efficiency as compared to synthetic N fertilizers. Nitrogen-rich processed manure materials such as scrubbing salts and mineral concentrates can meet these requirements (Hendriks et al., 2021; Hoeksma et al., 2021, Regelink, 2021, Reuland et al., 2021)

Scrubbing salts are solutions of ammonium sulphate or ammonium nitrate obtained from air washers or from nitrogen strippers. The agronomic efficiency in field trials is similar to that of synthetic N fertilizer (Hendriks et al., 2022, Sigurnjak et al., 2024). Scrubbing salts can meet criteria of the FPR and are therein classified as inorganic fertilizers. Hence, the current distinction based on origin of scrubbing salts is confusing i.r.t. the FPR and lacks a scientific justification.

Mineral concentrates and liquid fractions are produced through mechanical separation techniques. Liquid fractions from digestate after centrifugation or screen belt press typically comply with the TOC to total-N ≤3.0 criteria. More limiting is the criterium of mineral-N to total-N ratio which requires additional polishing steps to remove fine particulate matter from the liquid manure (Regelink, 2021, Reuland et al., 2021). Mineral concentrates from reverse osmosis installations can comply with both criteria (Hoeksma et al., 2021) and were tested in field trials on maize- and grassland showing very similar yields as compared to their synthetic counterparts (e.g. urean) (Ehlert, 2022, Van Middelkoop, 2017). Ammonia emissions from mineral concentrates are about 50% lower compared to emissions from manure slurries do to their lower viscosity and hence larger infiltration rate (Rietra & Velthof, 2014). Nevertheless, low-emission application of mineral concentrates is crucial in order to gain similar yields and should be mandatory as also proposed by the JRC (Huygens et al., 2020). Overall, mineral concentrates can be used safely in NVZs as they do not pose a greater risk for nitrate leaching as compared to synthetic fertilizer.

It should be noted that the legal effective N coefficient for RENURE materials for N application is by definition 100%, e.g. equal to synthetic N fertilizer. This condition already guarantees a safe use of RENURE materials. Stringent criteria for RENURE materials implies higher costs, higher energy consumption and larger dosages of additives needed to produce such materials (Regelink et al., 2021) whereas their environmental performance may be very similar to RENURE materials complying with less stringent criteria. It is advised to also consider also other possibilities to increase nutrient-use-efficiency from manure such as anaerobic digestion to increase mineral-N or by accounting for the multi-annual release of N from manure-based fertilizers.

Towards a Nutrient Directive including balanced fertilization of phosphorus

Phosphorus, though not mentioned in the main text of the ND, is indirectly covered by the ND as MS are required to report the level of eutrophication of surface waters which can be caused by N as well as by P. However, the EU reporting on the ND does not distinguish between eutrophication caused by N versus P (COM/2020/635) whereas different types of actions are needed to reduce leaching of P compared to N. The ND should be extended to cover also losses of P from agricultural soil in order to take adequate measures to either reduce N or P.

As the result of historic P fertilisation, agricultural soils can harbour large quantities of legacy P. Data from the EU-wide LUCAS database show that soils with high P levels and high risks of P losses are not restricted to regions with intensive livestock farming but occur all over Europe (Muntwyler et al., 2024, Tóth, 2014). However, only four MS have yet implemented limits for P application rates at farm or field level (Tzilivakis et al., 2020). Excessive P fertilisation leads to accumulation of P with soils and this can control P leaching rates for decades. Hence, there is a need for harmonized rules on phosphorus application limits in the EU.

Although legacy phosphorus can control P leaching rates for decades and lowering P levels in soil requires long-term measures (van Middelkoop et al., 2016) which is in part due to the large reservoir of legacy phosphorus present in Dutch agricultural soils (≈2000 kg P/ha) (Demay et al., 2023), a generic measure such as lowering P application standards might not effective in reducing P losses on the short term. Site-specific approaches are needed to reduce leaching from local hotspots and prevent surface runoff of particulate matter and associated P (Regelink et al., 2013). Examples of hotspots are fields with very high levels of soluble phosphate adjacent to streams. Lime application to increase soil pH and addition of iron-oxide sludge are both simple and cost-effective ways to rapidly reduce the leaching risk in soils with high levels of soluble phosphate concentrations (Rietra et al., 2024). Particulate material lost from soils through surface runoff is generally rich in P (Rietra et al., 2024) and release of phosphate from sediment was found to be a dominant factor in controlling phosphate concentrations in lowland rivers in Flanders (Smolders et al., 2017). Overall, this calls for (i) generic measures to prevent accumulation of P in agricultural soils and (ii) site-specific actions, in harmonization with the Water Framework Directive, to prevent leaching and runoff of P and end-of-pipe measures to reduce P levels in water bodies.

Temporal and spatial variation in nitrate concentrations

The ND lacks specificity about the 'system boundaries' where the target level of 50 mg NO_3/l has to be reached (e.g. upper or deep groundwater; each sampling point of a field or averaged on a certain area; each moment or averaged over the year; frequency of the measurements). Consequently, there is a lack of harmonization between the monitoring approaches and reporting by MS. The Netherlands report nitrate concentrations measured in the upper groundwater e.g. leachate (Van Duijnen et al., 2021). Nitrate concentrations in deep groundwater (5-15 m below surface) are lower and have not exceeded the target value of 50 mg/l since the start of the monitoring in 1984. Nitrate concentrations in leachate respond quicker to management changes and measures than deep groundwater (less delay-time), but are also more prone to temporal and spatial variation.

Temporal variation in nitrate concentrations occurs due to changes in weather conditions between years and this variation is expected to increase with enhanced climate change. The increase of nitrate concentrations in groundwater in the period 2019 – 2021 has been attributed to prolonged periods of drought during the growing season of these three subsequent years. Drought increases nitrate concentrations through three pathways namely a (i) lower nitrate uptake due to lower crop production, (ii) lower denitrification rates and (iii) less dilution due to a lower precipitation surplus. To account for temporal variations, MS should be allowed to assess trends over time spans of five years or longer. Similarly, NAPs have a timespan of four years which is short compared to the timespan on which measures can be expected to have an identifiable effect on ground- or surface water. As a consequence, new measures for the next NAP have to be defined when the effectiveness of the previous measures has not yet been determined. Suggestion is to prolong the timespan of NAP to six years, aligning it with the timespan of the river basin management plans in the Water Framework Directive.

Spatial variation in nitrate concentrations occurs as a results of differences in soil type and land use. In The Netherlands, lowest nitrate concentrations are found in groundwater under peat soils followed by clay soils due to the high denitrification capacity of those soils. Highest nitrate concentrations are found in groundwater below loess soils due to poor denitrification potential, poor water retention capacity, and a predominance of arable and vegetable farms in this region. Sandy soils have an intermediate position and show a clear distinction between the higher well-drained soils and the lower poorly drained sandy soils. In the latter, nitrate concentrations in groundwater are substantially lower due to higher denitrification rates (Fraters et al., 2012; 2020).

Nitrate concentrations are typically lower in groundwater of derogation farms due to the prerequisite to use 80% of their land for grassland. Arable farming and in particular vegetable farming show higher nitrate concentrations (Fraters et al., 2020). Studies regarding underpinning of N application standards in The Netherlands show that on leaching-sensitive soils, N fertilization levels to meet nitrate goals are far below recommended levels for many arable and horticultural crops (Schröder et al., 2004). Specialised vegetable farms are characterized by intensive cropping systems (> 1 crop per growing seasons) and for many crops a considerable amount of N is left in crop residues. Although adjusted management can help to further decrease nitrate leaching, it remains questionable whether the target level for nitrate can be met on vegetable farms. Hence, a strict interpretation of the limit of 50 mg/L, e.g. in each monitoring point, would seriously impair possibilities for specialised vegetable farming even on a small scale. The ND should therefore be clear on when targets are met both in terms of sampling depth, in terms of timespan for trend evaluation and in terms of averaging nitrate concentrations over spatial units.

Farmer community asks for simpler and more flexible regulation

Generally, the current support for the European farming-related policies among the farming community is low, as evidenced by the recent protests in various EU countries. In the Netherlands, surveying acceptance of farmers' about agri-environmental policies in the past decades (De Lauwere et al., 2016; Termeer, 2007) showed that farmers accepted the existence of a manure policy and intended to comply with it. However, farmers experience contradictory environmental objectives, high costs and complexity, fraud, little room for tailor-made solutions, and a lack of flexibility in the current regulation. Desired solutions that they mentioned were a simpler and more flexible manure legislation with compensatory measures, a more coherent policy, a smoother process for issuing permits for manure processing and a greater focus on soil fertility. They perceived the policy more as detrimental rather than beneficial, while the scores concerning its feasibility were around neutral (De Lauwere et al., 2016). They considered it likely that the manure policy negatively affected their farm results, focused on restricting livestock farming on national level, had a negative influence on job satisfaction and cost them a lot of time and effort. The surveyed farmers also had the feeling that they stood on the opposite side of the policy makers responsible for the manure policy. In 2024, the farmers' perceptions about manure policy in the Netherlands will be studied again. The results of this study are expected in the summer of 2024. It is however expected that recent policy measures including phasing out of the derogation for grassland, implementation of bufferzones and designation of nutrient-polluted zones has further decreased farmers acceptance of manure policy as these measures directly impact farmers income.

It is the challenge for policymakers to implement effective and proven measures for a longer period in future regulation, this may increase acceptance of manure policy by farmers.

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