European Union Network for the Implementation and Enforcement of Environmental Law

Trend reversal in groundwater pollution

Good practice examples and recommendations

Date of report: 25 October 2023

Report number: 2022(VI)WG3

Introduction to IMPEL

The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is an international non-profit association of the environmental authorities of the European Union (EU) Member States, and of other European authorities, namely from acceding and candidate countries of the EU and European Economic Area (EEA). The association is registered in Belgium and its legal seat is in Brussels, Belgium.

IMPEL was set up in 1992 as an informal Network of European regulators and authorities concerned with the implementation and enforcement of environmental law. The Network's objective is to create the necessary impetus in the European Community to make progress on ensuring a more effective application of environmental legislation. The core of the IMPEL activities concerns awareness raising, capacity building and exchange of information and experiences on implementation, enforcement and international enforcement collaboration as well as promoting and supporting the practicability and enforceability of European environmental legislation.

During the previous years IMPEL has developed into a considerable, widely known organisation, being mentioned in a number of EU legislative and policy documents, e.g. the 8th Environment Action Programme that guide European environmental policy until 2030, the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" on Flagship 5 and the Recommendation on Minimum Criteria for Environmental Inspections.

The expertise and experience of the participants within IMPEL make the network uniquely qualified to work on both technical and regulatory aspects of EU environmental legislation.

Information on the IMPEL Network is also available through its website at: www.impel.eu

Title of the report:	Number report:
Trend reversal in groundwater pollution – Good practice examples and recommendations	2022(VI)WG3
Project Manager/Authors: Thomas Ormond / Tim Besien, Astrid Bischoff, Saartje Degelin, Andrea Fazzone, Sebastien Janssens, Ville Keskisarja, Valeria Marchesi, Thomas Ormond, Susie Roy, Cristina Zocchia	**Report adopted at IMPEL General Assembly Meeting**: 29-30 November 2023 Madrid **Total number of pages: 58** Report: 56 Annex: 2

Executive Summary

About 25 % of the groundwater bodies in the EU are in poor chemical status, mostly due to pollution with nitrates and pesticides from agricultural sources. In contrast to the obligation under the Water Framework Directive to reverse upward trends in the concentration of pollutants, the groundwater body area with an upward pollution trend is still nearly double the area with a trend reversal. It is thus urgent to find ways how to improve the implementation of EU water law.

The IMPEL "Trend reversal" project from 2020-2023 aimed to promote an exchange of information and experiences between water authorities in Europe and to develop guidance on best practices of achieving a trend reversal in groundwater pollution. The German-led project team consisted of experts from 5 EU Member States and the UK; altogether 17 authorities from 13 IMPEL member countries participated actively in the project. On the basis of a survey, further research and input from a mini-conference with external experts, a guideline with good practice examples and recommendations was developed and finalised in October 2023. The practice examples include the successful experience of Denmark with reducing nitrate pollution since the 1980s, the changing schemes for groundwater catchment protection in England, experiences in the German state of Hessenn with cooperation agreements in water protection zones, measures to reduce pesticide pollution of groundwater in the Italian region of Lombardy, and the Belgian (Flemish) practice of guiding farmers in the context of the Ntrates Directive. The guideline contains 16 conclusions and recommendations plus an Annex with bibliography and useful links.

Disclaimer

TABLE OF CONTENTS

1. INTRODUCTION

Art. 4 of the Water Framework Directive (WFD) obliges Member States, among other things, to protect, enhance and restore all bodies of groundwater with the aim of achieving good groundwater status by December 2015, and to implement the measures necessary to reverse any significant and sustained upward trend in the concentration of pollutants. In actual fact however, 24 % of groundwater bodies in the EU were in poor chemical status in 2015 (1 % status unknown), mostly due to pollution with nitrates and pesticides from agricultural sources. Moreover, according to an EEA report of 2018[1], the total groundwater body area with an identified upward trend of pollution was then still nearly double the area with a trend reversal (9.9 % against 5.9 % of area). The findings from the following planning cycle (2015-2021) are not yet publicly available but there is reason to believe that the trends have not significantly changed in the last years.[2]

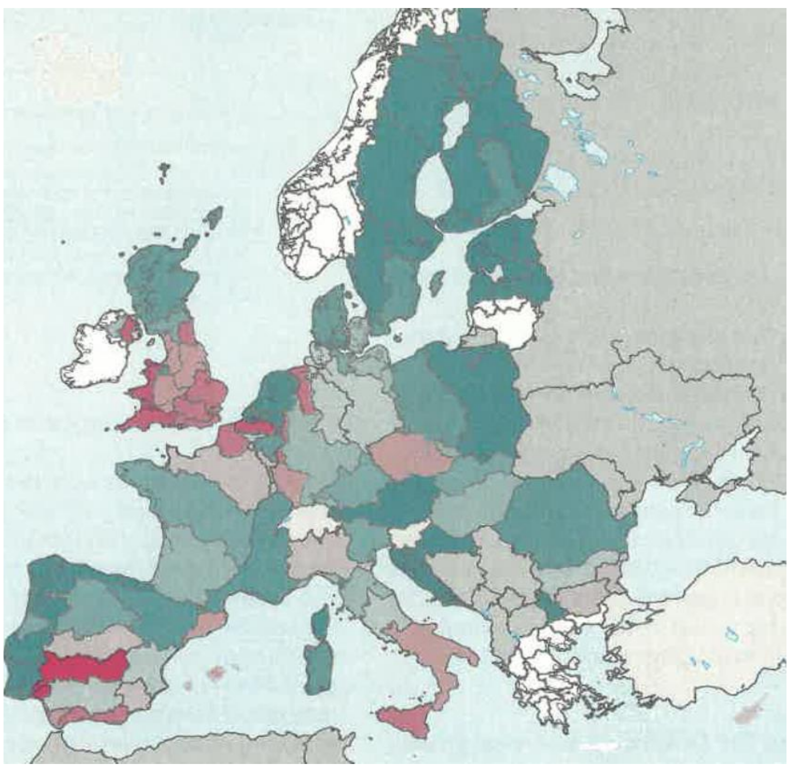


Fig. 1.1:
EU groundwater bodies failing to achieve good status

(Source: EEA Report 7-2018 – „European waters“, p. 51)

Percentage of area of groundwater bodies not in good chemical status per river basin district (RBD) in second RBMPs

(0 % = dark blue,
100 % = dark red)

[1] European waters. Assessment of status and pressures 2018. EEA Report No. 7/2018.

[2] Cf. Chapter 2 below and current website information of EEA on https://www.eea.europa.eu/publications/europes-groundwater and the WISE dashboard on https://water.europa.eu/freshwater/europe-freshwater/water-framework-directive/groundwater-chemical-status.

The monitoring and assessment of the quantitative and chemical status of groundwater bodies has improved, according to the EU Commission's Report of 2019 on the implementation of the Water Framework Directive, although a significant number still lacks proper monitoring sites. Here, the WFD is complemented by the Groundwater Directive, which specifies the list of relevant pollutants for which risk posed to groundwater should be considered, how threshold values should be set and trends analysed for the assessment of chemical status. Both directives work in synergy also with other EU law, such as the Drinking Water and Nitrates Directives. Chemical status monitoring is seen by the Commission as "still substandard, with a large number of groundwater bodies either lacking or monitoring a limited part of the core parameters". [3]

Groundwater pollution can involve many different substances from a range of sources and activities. In urban areas, contamination by old industrial sites, petrol stations and chemical dry-cleanings as well as from leaking sewage pipes and oil tanks plays a major role. In areas with extensive mining, the landfilling of mining waste, pollutants washed out by mining operations or salt injections by the potash industry can affect groundwater bodies. Saline intrusion into groundwater is increasingly a problem for islands and coastal areas, due to rising sea levels and increased abstraction driven by climate change. But on the whole, in terms of the geographical area and the number of EU Member States and groundwater bodies affected, agriculture is the major driver for the failure to reach good chemical status in many European groundwater bodies, due to the widespread over-application of fertilizers and pesticides. According to reporting in the Water Information System for Europe (WISE), 3,222 groundwater bodies (24 %), representing about 31 % of the total groundwater body area in the EU, were assessed in 2016 as being at risk of failing good chemical status objectives. For 1,431 groundwater bodies the risk is due to nitrate, which is by far the most frequent reason causing risk. In second place come pesticides, followed by chloride, sulphate, lead, ammonium, nickel and arsenic. These substances lead to risk of failing WFD objectives in at least 10 Member States.[4] The 2019 implementation report of the EU Commission sums up that the biggest challenges in addressing the poor quality of water related to agricultural activities were found in Bulgaria, the Czech Republic, Germany, Spain, Croatia, Hungary, Poland and the United Kingdom.[5]

---

[3] Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC). Second River Basin Management Plans / First Flood Risk Management Plans, of 26.2.2019, COM(2019)95 final, p. 5 et seq.

[4] Report from the Commission (fn. 3), p. 134.

[5] Report from the Commission (fn. 3), p. 15.

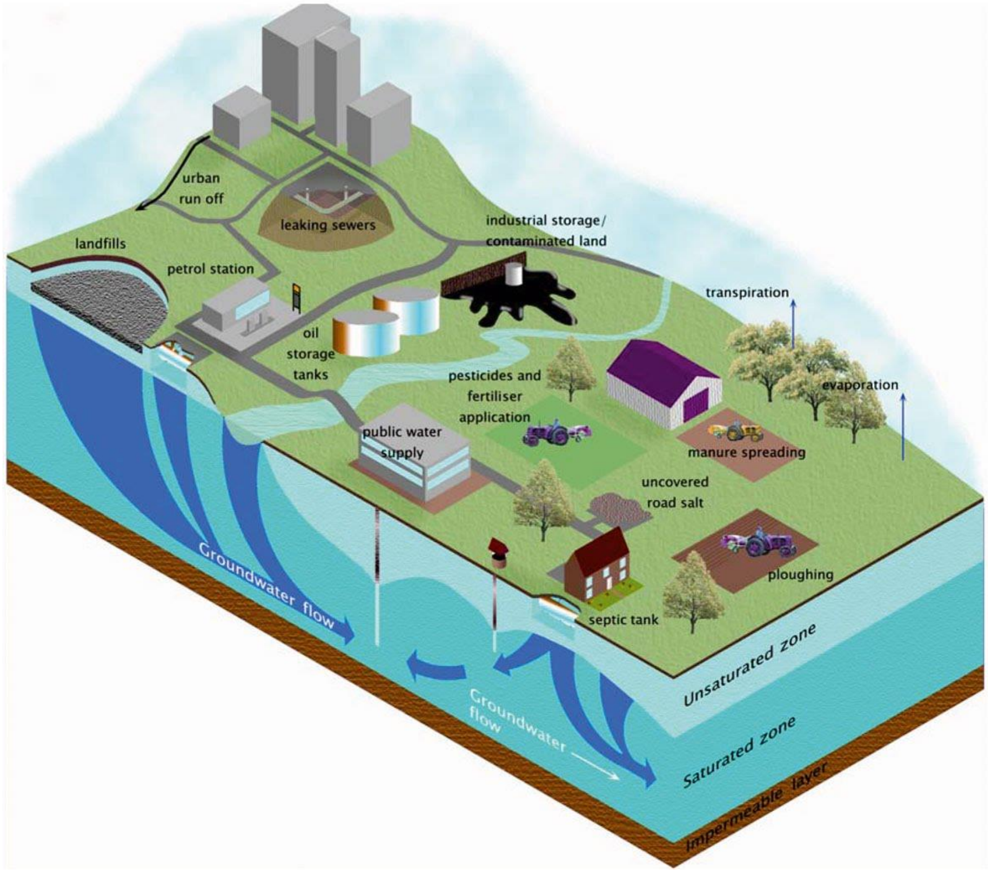


Fig. 1.2:
The hazards posing a threat to the quality of groundwater

(Source:
UK Groundwater Forum, http://www.groundwateruk.org/Image-Gallery.aspx)

To meet the challenges, the WFD (Article 11) envisages a set of basic and, where necessary, supplementary measures to be included in the programmes of measures for each river basin district. Notably, Art. 11(3)(h) of the WFD requires that "for diffuse sources liable to cause pollution", measures to prevent or control the input of pollutants are put in place. Controls may take the form of a requirement for prior regulation, such as a prohibition on the entry of pollutants into water, prior authorisation or registration based on general binding rules where such a requirement is not otherwise provided for under Community [now Union] legislation. These controls shall be periodically reviewed and, where necessary, updated". As regards supplementary measures, Art. 11(4) WFD points to the non-exclusive list in Part B of Annex VI to that Directive. This list starts with legislative and administrative instruments, mentions among other things economic or fiscal instruments, negotiated environmental agreements, emission controls and codes of good practice, and ends with educational, research, development and demonstration projects.

Against this background, the IMPEL "Trend reversal" project has looked especially at the experience of participant countries and tried to derive good practice examples which could be a basis for a number of recommendations on how reversal in groundwater pollution trends can be achieved.

2. STATUS, TRENDS AND STRATEGIES IN THE PARTICIPANT COUNTRIES

Introduction

Following on from the description of the legislative setting for trends assessment in Section 1, here the current status of groundwater at the European level, implementation of trends assessment and tools used by various MS are discussed.

European wide groundwater body status and trends

In reporting on groundwater body status, each participating country or member state also needs to take into account trends in groundwater quality either through the chemical status assessment or quantitative (saline intrusion) tests. Since the adoption of the WFD in 2000, the chemical and quantitative status of groundwater bodies (GWBs) has been assessed through the 6 year river basin management planning (RBMP) cycle. The chemical status of GWBs is assessed through the reviewing the evidence for:

- pollution of the groundwater body as a whole (general chemical test);
- impacts on drinking water protected areas;
- evidence of saline intrusion with a crossover with quantitative status;
- impacts on groundwater associated aquatic ecosystems;
- impacts on groundwater dependant terrestrial ecosystems tests; and
- statistically and environmentally significant upward trends in pollutant concentrations.

The results of status assessment are reported in RBMPs.

By the 2nd RBMP groundwater in the EU (EU28 countries) was still under significant pollution and abstraction pressure. Although 81% of the GWBs, covering 74% of the GWB area in the EU were at good chemical status, 15% of GWBs did not achieve good status and 4% were at unknown status. Out of the nearly 160 synthetic and naturally occurring substances leading to poor chemical status, the main pollutant leading to poor status was nitrate which affected 9% of GWBs covering 18% of the GWB area, followed by pesticides. Other commonly reported parameters leading to poor status were ammonium, chloride, sulphate, lead, nickel and arsenic. The main drivers and pressures acting on GWBs and leading to poor status include agriculture with 20% of the EU 27 GWB area being affected by agricultural diffuse pollution and 7% by agricultural abstraction; the supply of water to the public (7%); discharges from scattered dwellings non-connected to sewerage networks (5%); point source pollution from abandoned industrial or contaminated sites (4%); point source pollution from industrial plants regulated under the Industrial Emissions Directive (4%).

In terms of trends assessment EEA analysis of WFD status reporting data for nitrate suggest that concentrations in groundwater bodies have risen slowly over the past 20 years.

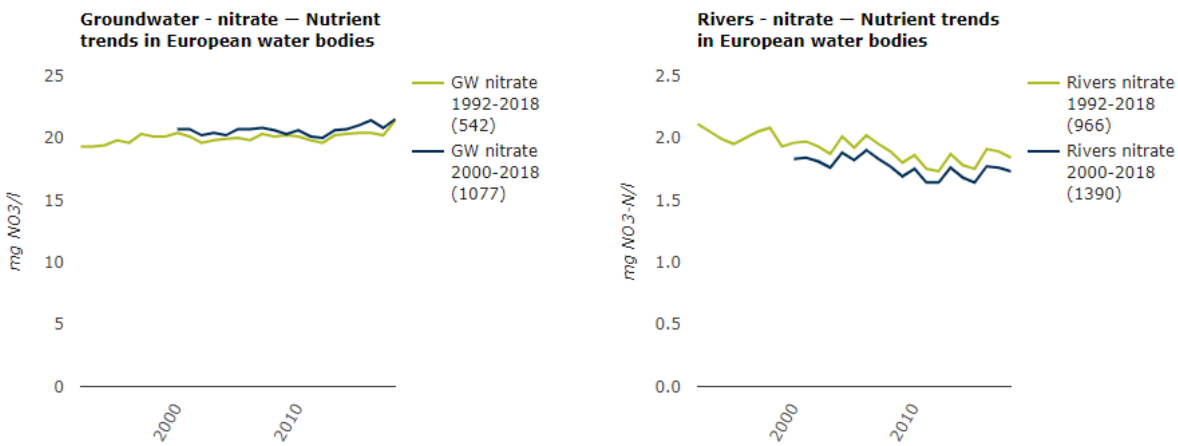


Fig. 2.1 - *Nutrient trends in European water bodies (Source: European Environment Agency)*

Summary of groundwater pollution trends in participating countries

Participating countries of this IMPEL project which returned a response to the questionnaire titled "Trend Reversal in Groundwater Pollution" for information at national or regional scale were Denmark, Finland, Germany (Hessenn and Berlin), Italy (Lombardy), Luxembourg, Malta, the Netherlands, Portugal, Romania, Sweden, Slovakia, the UK (England, Northern Ireland and Scotland).

The results of this survey are summarized in a separate report (Analysis of the responses to the questionnaire, by *Natalie Sims and Susie Roy,* revised 25 Sept. 2023). In the 16 replies, poor chemical status and trends were reported as being mainly due to nitrate concentrations, with chloride (linked to coastal and minewater intrusion) and pesticides also mentioned. The key reasons and actors noted were agriculture for nitrate and pesticides, and abstraction and sea level rise (climate change related) for chloride. In the Hessian region of Germany minewater intrusion from the potassium industry was also identified as the reason for locally rising chloride pollution of freshwater aquifers. The wastewater sector and landfills, where there was a lack of connection to treatment facilities were noted in the Romanian response as previously having been a source of nitrate, although legislation on urban wastewater treatment has led to improvements.

Monitoring data for trends assessment was mainly collected through WFD-related monitoring and also the overlapping (but not duplicating) Nitrates Directive (91/676/EEC) monitoring networks. Significant trends in data were identified through use of statistical tests using linear regression and the non-parametric Mann-Kendall and Sens tests for trends in groundwater quality data. In most countries which reported on significant trends (mainly for nitrate), these were typically stable, although there was a mix with upward downward trends identified. It was expected that the rising trends would continue as they reflected historical inputs to the groundwater systems.

The time lag for aquifers to improve quality as a result of changes in inputs of pollutants to groundwater was commonly noted as key reason for only a small number of trend reversals being identified. In Germany (Hessian region) monitoring of nitrate in soil water and the unsaturated zone has been undertaken to better understand the likely future impact of mitigation measures. Malta have invested in monitoring which will enable the understanding of fluxes of groundwater and chemicals in the unsaturated zone porewater to similarly be able to assess likely future trends without having to wait for the groundwater time-lag.

Strategies and measures for trend reversal

Comparing the strategies and methods to achieve a trend reversal, a variety of approaches can be identified. Denmark on the one hand, where serious problems with nitrates and pesticides in groundwater threatened the supply with clean drinking water already in the 1980s, addressed the problem systematically with a National Action Plan and a range of stringent measures. This included tools like a compulsory accounting system for the use of fertilisers, maximum levels for animal stock density, requirements for better handling and utilization of nitrogen in manure, maximum N-quotas for specific crops, and recently the obligatory use of catch crops.[6] On the other hand, most EU countries with nitrate problems – and also those participating in this IMPEL project – relied preferably on voluntary agreements between water suppliers and farmers, more or less generous financial incentives and state-funded consulting services. Denmark also modified its policies in 2016, by switching to more geographically targeted mitigation measures as a supplement to the general regulations and by allowing the use of more fertilisers, in order to improve economic conditions for farmers.

[6] See below Chapter 2 and e.g. *Stephen Foster / Troels Kaergaard Bjerre*: Diffuse agricultural pollution of groundwater - addressing impacts in Denmark and Eastern England, in: Water Quality Research Journal (2023) 58 (1), pp. 14-21; presentation by *Birgitte Hansen* at the IMPEL mini-conference in Frankfurt, 4.9.2023, and cf. other articles mentioned in the Annex.

In the survey for this project, several responses mention the measures already taken under the Nitrates Directive of 1991. These measures included identification of polluted groundwater, action plans, and regulation around nitrate-vulnerable zones (NVZ), as well as monitoring of trends. Some tentative identification of trend reversal linked to NVZs was mentioned in Scotland. In Denmark, the wide range of regulatory controls on the agricultural sector's use of fertilisers and manures made it difficult to understand which of the measures had most effect. An example of trend reversal caused by implementation of voluntary incentivised measures (pre-WFD) to control nitrate pollution was given from England in the use of Nitrate Sensitive Areas where farmers were compensated for loss of income from caps on application rates of nitrogen to arable and grassland.

The WFD River Basin Management Plans (RBMPs) have driven the use of water protection zones, groundwater protection zones and drinking water protected areas to deal with pollution of drinking water supplies through statutory or voluntary measures to reverse trends. In addition, the planning and monitoring required under RBMPs have demonstrated the long term strategic importance of groundwater protection helping to fund better and more innovative management. Payment for ecosystems services (incentivisation of land management for environmental benefits) has been implemented at different levels in different countries, some implementing this approach more widely, but perhaps with less positive impacts from voluntary measures, whereas other countries rely more on a wide of regulations to control pollution. In all cases, the need to ensure compliance with agreements or enforcement of regulation is key to making sure that groundwater is protected, and this requires investment in regulators to allow time for stakeholder engagement.

3. GOOD PRACTICE EXAMPLE 1: REVERSING NITRATE POLLUTION IN DENMARK

Historical background for regulation aiming towards a trend reversal of nitrate pollution

With more than 60% of the area of Denmark cultivated, as well as breeding of 1.5 mio. cattle and 13 mio. pigs [7], Denmark can be described as an agricultural nation.

After World War II, the use of artificial fertilizers was increasing in Danish agriculture, which resulted in an increase in excess nitrogen from agricultural sources (see Figure 3.1).

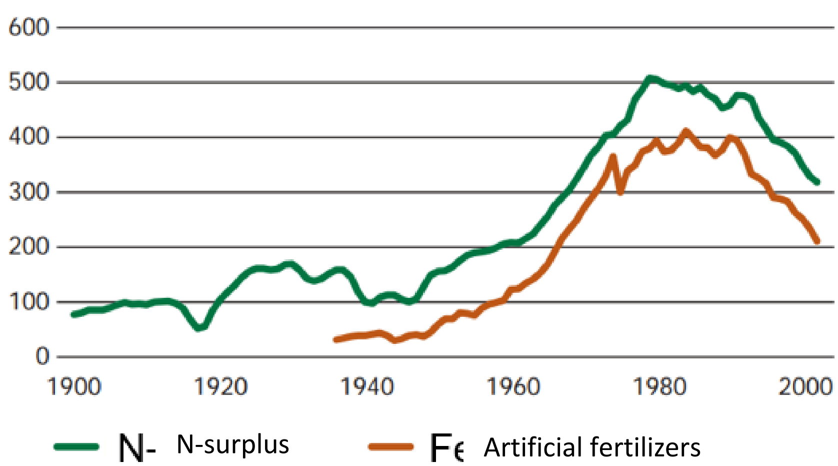


***Figure 3.1:** N-surplus and use of fertilizers in Danish agriculture (1000 tons N)*

In 1981, several events of oxygen depletion and eutrophication were observed in Danish coastal waters. In 1982, marine biologists connected these events to the increased use in artificial fertilizers.[8]

---

[7] https://www.dst.dk/da/Statistik/emner/erhvervsliv/landbrug-gartneri-og-skovbrug/det-dyrkede-areal

[8] Iltsvind og fiskedød i 1981 Omfang og årsager 1984 https://www2.mst.dk/Udgiv/publikationer/1984/87-503-4881-7/pdf/87-503-4881-7.pdf

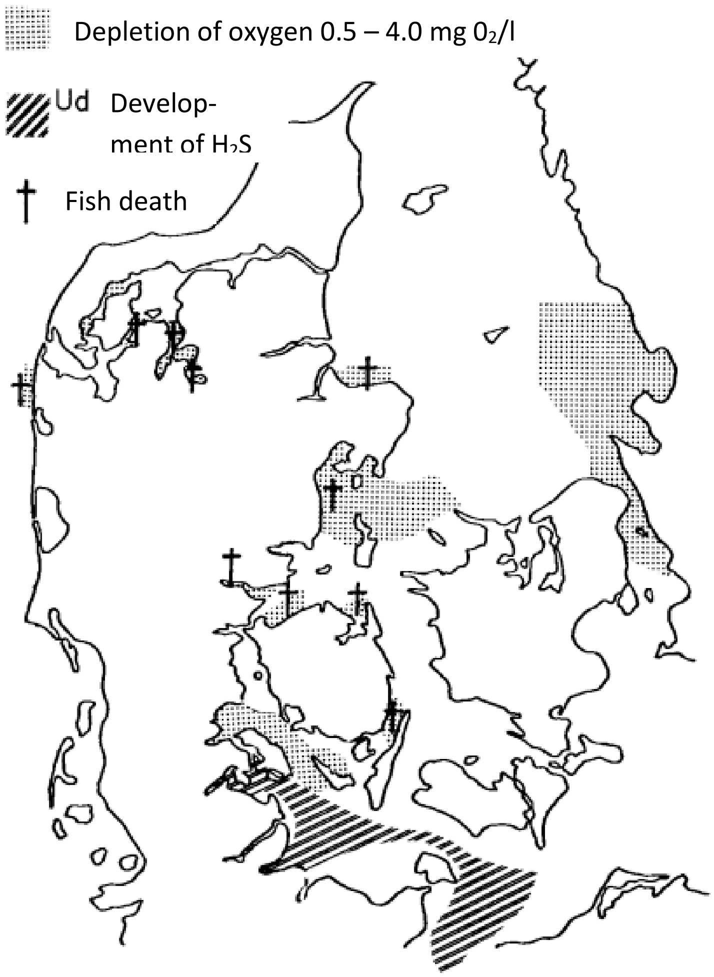


Figure 3.2: Minimal propagation of oxygen depletion, places with incidences of fish deaths and areas with development of hydrogen sulphate in 1981.

More major events with dead lobsters and fish, finally kick-started the trend reversal of nitrate trends in Denmark:

- Action Plan on nitrogen, phosphorus and organic matter (NPo) in 1985[9]
- First Danish Water Environmental Plan in 1987[10]

  Mainly focusing on phosphorous and nitrate from wastewater

[9] Tommy Dalgaard et al 2014 Environ. Res. Lett. 9 115002

[10] Beretning om Vandmiljøplanen - Beretning afgivet af miljø- og planlægningsudvalget den 30. april 1987

- In 1991, the EU introduced the Nitrates Directive, which aimed at reducing water pollution caused - or induced by nitrate from agricultural sources.[11]
- Second Danish Water Environmental Plan 1998 (Accepted as implementation of the Nitrate Directive)
  Goal of reducing 49% of nitrate emissions

- Water Framework Directive from 2000
  A framework to protect water quality and water quantity

- River Basin Management Plan 2009-2015 (in 2014), River Basin Management Plan 2015-2021 (2016) and River Basin Management Plan 2021-2027 (expected 2023)

Before implementation of the first Danish Water Environmental Plan in 1987, nitrate in groundwater originated mainly from two different sources, wastewater and agricultural use of fertilizer. As a result of the first Danish Water Environmental Plan, wastewater treatment was significantly improved Hence, more recently the most important source of nitrate in groundwater is considered to originate from diffuse sources, primarily agricultural activities.

After the first Danish Water Environmental Plan, further efforts on reducing nitrate loss to the aquatic environment has focused on minimizing discharge of nitrate to Danish coastal waters, also including agri-environmental schemes.

Regulation of manure and supplement of fertilizer for agricultural use in Denmark

As mentioned above Denmark is an intensively farmed country. Therefore, there is a high potential risk of nitrogen loss when managing inorganic and organic fertilizers on farms.

For livestock farming in Denmark, regulation has continuously been revised to ensure that pollution of groundwater and surface water with nitrate is significantly reduced.

One set of rules, the Livestock Manure Order (Order on environmental regulation of Livestock and on the storage of manure[12]), regulates the housing and storage facilities on livestock farms.

---

[11] Nitrates Directive, (Directive 91/676 of 12 december 1991)

[12] Bekendtgørelse om miljøregulering af dyrehold og om opbevaring af gødning (husdyrgødningsbekendtgørelsen) BEK nr 2243 af 29/11/2021

The handling and use of livestock manure is regulated by the Fertilizer application order[13].

Large parts of the Nitrates Directive[14] are implemented in parts of the Livestock Manure Order and the Fertilizer application order.

Below fundamental rules preventing accidental application of livestock manure to the environment and groundwater are highlighted.

Housing and storage facilities and handling of manure within the livestock farmstead:

Fig. 3.3: Manure tanks (Photo: Danish Environment Agency)

- Capacity of the storage tanks corresponding to no less than 6 months production and in most cases no less than 9 months.
- Solid, impermeable floors and well-functioning drainage system in animal stables and other similar constructions on farms.
- Technical requirements for storage of solid manure/compost/silage liquor, etc.
- Storage of manure may only take place in a manure yard made of durable materials that are impermeable to moisture or in a slurry tank.
- Requirements for drainage and drainage through closed pipes for liquid livestock manure, e.g. slurry and storage in tight and closed containers.

[13] Bekendtgørelse om jordbrugsvirksomheders anvendelse af gødning (Gødningsanvendelsesbekendtgørelsen) BEK nr 1142 af 10/07/2022

[14] Directive 91/676 of 12. december 1991

Application of fertilizers to the field:

In this context, the term "fertilizers" covers animal manure, digestate, silage liquor, processing waters and mineral (artificial) fertilizer.

Fig. 3.4: Field in Denmark (Source: Danish Environment Agency)

- Harmony between the amount of total organic nitrogen and the agricultural area available for manure application – max. 170 kg N per hectare and year.
- No application of liquid and solid animal manure or mineral fertilizer from harvest until 1 February as a main rule. Exceptions for certain crops and soil types (closed periods)
- No application of animal manure, digestate, silage liquor, processing waters or mineral fertilizer to water-saturated, flooded, frozen or snow-covered grounds

Other important national general binding rules:

- Obligatory fertilizing planning in the national (IT-based) Fertilizer Accounting system applicable to all farms in one of the following cases:
  - Farms with livestock that produces more than 1000 kg nitrogen per year or receiving the same amount of organic fertilizer
  - Farms with livestock that produces more than 100 kg nitrogen per acre of agricultural land receiving the same amount of organic fertilizer
  - Farms larger than 10 hectares, cultivated with crops with a fertilizer demand

Application of Nitrogen is limited on the basis of nationwide fixed nitrogen fertilization standards depending on crop, soil type and irrigation scheme etc. This results in a maximum N allowance at farm level accounting for all N-containing fertilizers (manure, artificial fertilizers, compost, sewage sludge, bio ash and others).

Obligatory catch crops schemes:

- Obligation for all farms (>10 ha) to establish catch crops or alternative nitrogen reducing measures on at least 10.7 % of the field area

- Obligation for farms with high livestock density (> 80 kg N/ ha) to establish catch crops on 14.7 % of the field area.
- Other mandatory schemes for catch crops on between 0 and 31 % of the field area
- In the year succeeding establishment of catch crops the nitrogen incorporated by the catch crops is accounted for with up to 25 kg N/ha.

Inspections

Fig. 3.5
Farm inspections in Denmark
(Source: Danish Env. Agency)

To secure that farmers comply with the environmental regulation there is a wide use of inspections in Denmark.

Inspection of compliance with laws and regulations on farms is shared between the 98 municipalities in Denmark, which constitute the local environmental authorities, and the Agricultural Agency.

The municipalities' inspections
The municipalities carry out compliance inspections concerning national environmental regulation of housing and storage facilities and the handling of manure within the livestock farmstead. A certain minimum frequency apply for these inspections. Moreover, the municipalities are responsible for inspecting certain regulations of the usage of manure and other fertilizers in the fields (closed periods and the prohibition of application to water-saturated, flooded, frozen or snow-covered grounds).

According to the Order on environmental inspection,[15] the authorities must perform basic inspections at least every third year (category 1) or every sixth year (category 2) depending of the size of the livestock farm. In addition, the authorities perform priority inspections, so that environmental inspections are targeted, which constitute the largest risk for the environment within the authority's geographical area of responsibility.

[15] Bekendtgørelse om miljøtilsyn (Miljøtilsynsbekendtgørelsen) BEK nr. 1536 af 09/12/2019.

The aim is at least 40% of category 1 livestock farms inspected physically each year. For category 2 livestock farms the aim is physical inspection of at least 25 % each year.

The enforcement measures are: Dialogue, enforcement notice, injunction, fines, prosecution.

The Inspections are systematically planned using an inspection plan and are carried out systematically, for example by using check lists. They are finalized with an inspection report and – if necessary – enforcement.
The inspections are carried out as:

- Spot checks or regular inspections of all farms – depending on the topic for the control
- Partially "risk based" selection of farms

The Agricultural Agency's inspections
The Danish Agricultural Agency carries out inspections of fertilizer accounts, catch crops schemes and cross-compliance control concerning application of fertilizers to the field as well as regulation of animal housing and manure storage on farmsteads and also concerning plant cover in sensitive periods.

The Danish Agricultural Agency is responsible for inspections and ensuring that payout of national - and EU subsidy schemes is based on reliable information. Direct inspections are carried out in accordance with EU-regulations, and the EU conducts regular inspections to ensure that Denmark and the remaining EU member states comply with common guidelines. Non- compliance with the rules results in reduced direct payments to the farmer by the European Union support payments.

The enforcement measures are: Enforcement notice, injunction, fines, prosecution.

Inspections of catch crops schemes are carried out for either a 1 % or 10% sample of all farms depending on the specific catch crops scheme. A small number of the inspections are selected randomly, whereas the majority of inspections are selected based on a riskbased-analysis with input from satellite imagery time-series analysis using images from end of August to beginning of October. The purpose of the satellite-based analysis is to predict the presence of catch crops on individual fields and hence identify fields with a low probability of catch crops.

Results in the field balance

As shown in figure 3, the regulations and methods applied in Denmark, have reduced the nitrogen field balance by more than 40 % from 1990 – 2020 without a decrease in yields. This reduction is mainly caused by a decrease in the use of inorganic fertilizers. It also appears that the reduction in the field balance is followed by a reduction in N-deposition.

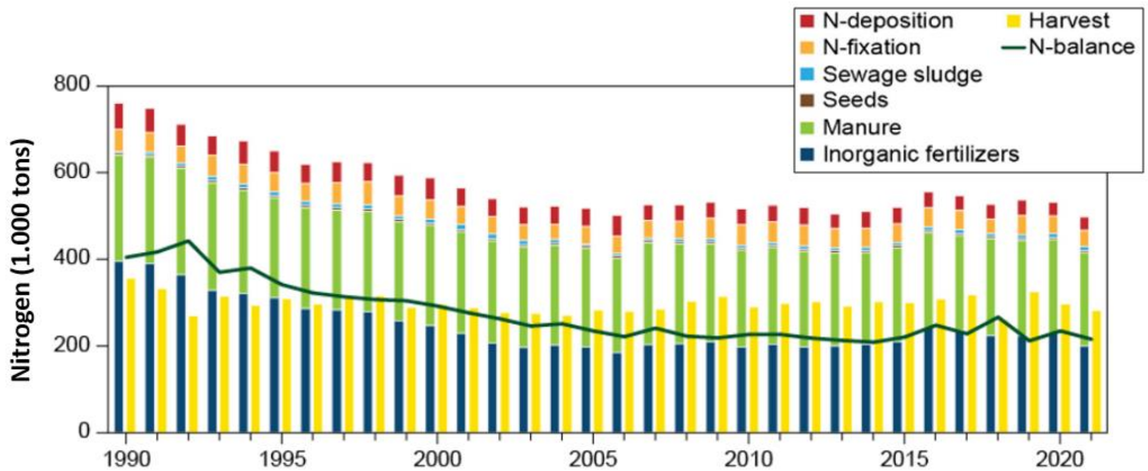


Figure 3.6: Danish field balances for nitrogen (solid line) [16]

Monitoring of nitrate in Danish groundwater

Denmark receives more than 99% of its drinking water from groundwater. Therefore, the country has a long tradition of monitoring and documenting the quantitative and qualitative status and trends of groundwater.

The Danish groundwater-monitoring programme was originally designed to monitor recent groundwater recharged after approx. 1940. Implementation of the Water Framework Directive has required adjustments of the groundwater monitoring network and thus some monitoring points, used for previous reporting periods of the Nitrates Directive, are closed and new are established during the last reporting periods. The adjustment resulted in a geographically more distributed monitoring network, representing the Danish groundwater bodies.

To represent the groundwater bodies in different depth, many monitoring wells have several screens in different depths, which shows the vertical differences of nitrate concentrations in the same geographical location.

Monitoring wells are placed in quaternary glacial deposits, tertiary fluvial deposits or in cretaceous limestone. Because the national groundwater monitoring programme has been designed to monitor groundwater recharged, wells are mainly placed in aquifers having a significant flowrate.

---

[16] Landovervågningsoplande 2021. NOVANA https://dce2.au.dk/pub/SR526.pdf

Number of groundwater monitoring points			
	2012-2015	2016-2019	common points
Phreatic groundwater (0-5m)	73	77	68
Phreatic groundwater (5-15m)	362	392	338
Phreatic groundwater (15-30m)	439	462	412
Phreatic groundwater (>30m)	336	344	287
Captive groundwater			
Karstic groundwater			

Figure 3.7: *Vertical distribution of groundwater monitoring points for the last two reporting periods of the nitrate directive[9].*

Over the last 12 years, i.e. over the last three reporting periods of the Nitrate Directive (2008-2011, 2012-2015 & 2016-2019), groundwater from in total 1,623 monitoring points have been analyzed for nitrate over time. 929 points of those 1,623 monitoring points are common for all of the three last periods of the nitrate directive. Captive and karstic groundwater is not monitored in Denmark, because the natural quality in captive groundwater makes them unsuitable for drinking water, and thus the karstic limestone aquifers are considered insignificant.

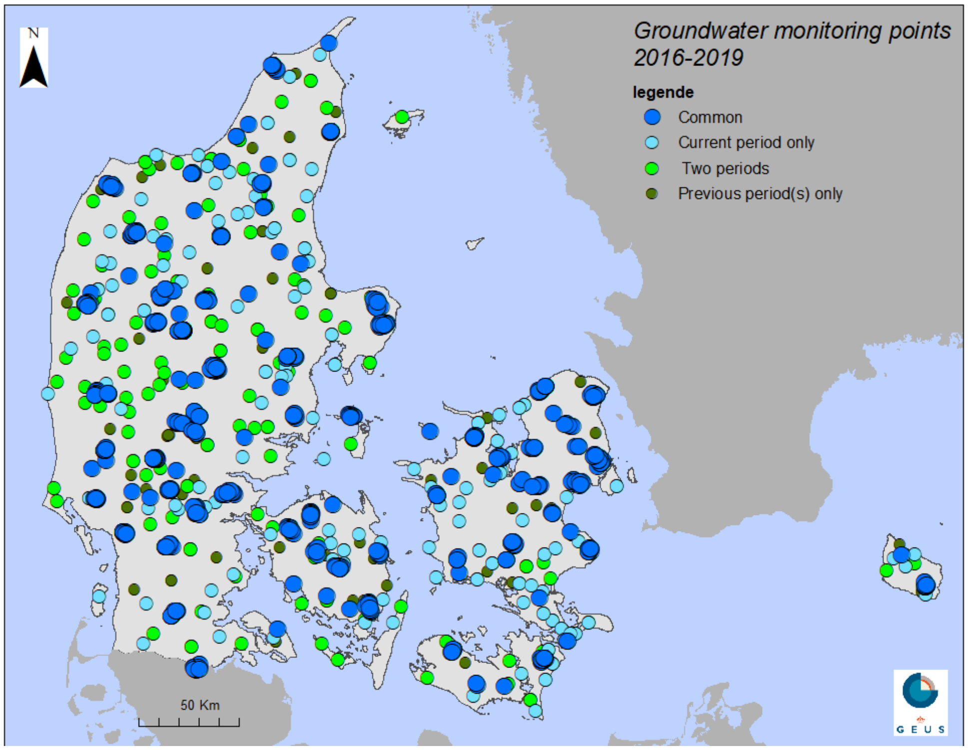


__Figure 3.83:__ The location of the 1,623 groundwater monitoring points in Denmark available for the last 3 reporting periods of the nitrate directive (2008-2019). The large blue signature shows the 929 common monitoring points for the last three periods of the nitrate directive (2008-2019). Light blue signature shows monitoring points only available for the reporting period from 2016-2019. Monitoring points used in the current period and one of the previous periods (2008-2011 or 2012-2015) are shown in light green. Finally, the dark green signature shows monitoring points with data from one or both of the previous periods (2008-2011 / 2012-2015)[17].

Status and development of nitrate concentrations in Danish groundwater

Nitrate is found in 55% of all monitoring points from 2016-2019, with average nitrate concentrations > 1 mg/l. About 14% of all monitoring points exceeds the EU threshold value for nitrate (50 mg/l). Elevated nitrate concentrations in shallow groundwater are distributed evenly in Denmark, while elevated nitrate concentrations in deeper groundwater are mainly found in the western part of Denmark. This reflects the difference in distribution of protective clayey geological layers, such as regional differences in natural nitrate reduction processes.

[17] Ministry of Environment of Denmark, 2021 "Status and trends of the aquatic environment and agricultural practice in Denmark - Report to the European Commission for the period 2016-2019 in accordance with article 10 of the Nitrates Directive (1991/676/EEC)" at https://cdr.eionet.europa.eu/dk/eu/colqyikgg/envyhl1rq

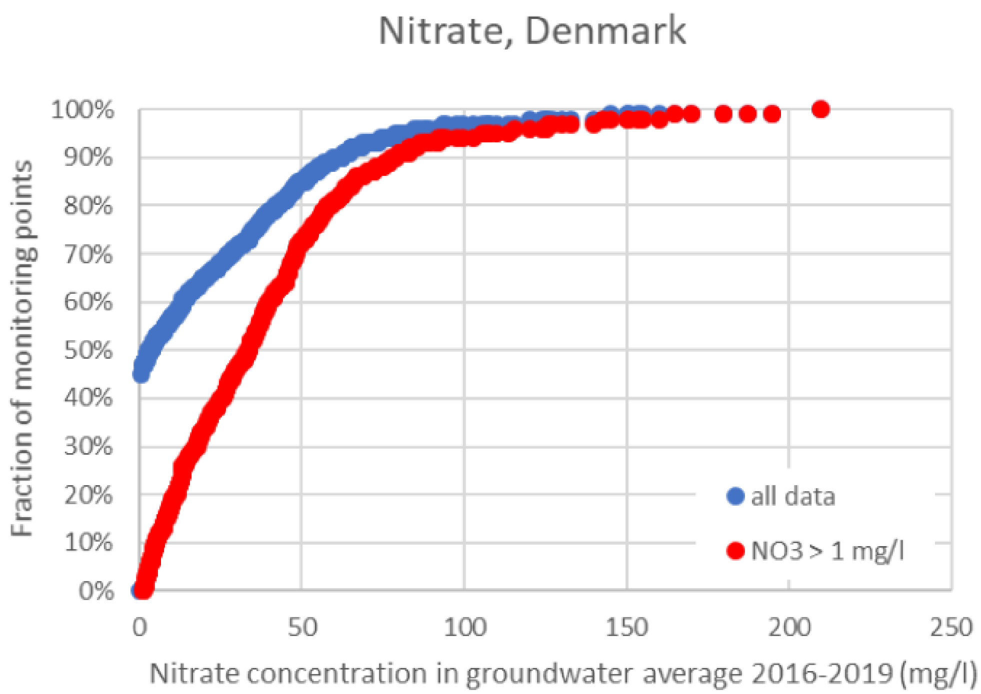


Figure 3.9: The distribution of the average nitrate concentrations of the individual monitoring points 2016-2019. The distribution is shown for all monitoring points and monitoring points with an average nitrate concentration above 1 mg/l[18].

Nitrate trends in Danish groundwater

Nitrate trends in Danish groundwater are assessed between the previous and the current nitrate directive reporting periods (2012-2015 and 2016-2019)[10]. It was possible to calculate trends for the 1,105 common monitoring points within the two reporting periods.

[18] Ministry of Environment of Denmark, 2021 "Status and trends of the aquatic environment and agricultural practice in Denmark - Report to the European Commission for the period 2016-2019 in accordance with article 10 of the Nitrates Directive (1991/676/EEC)" at https://cdr.eionet.europa.eu/dk/eu/colqyikgg/envyhl1rq

Nitrate trends for the 1105 common monitoring points	Percentage of common point trends
Strongly increasing >+5 mg/l	10.7
Weakly increasing >+1 to +5 mg/l	7.6
Stable ±1 mg/l	50.4
Weakly decreasing <-1 to -5 mg/l	12.4
Strongly decreasing <-5 mg/l	18.9

Figure 3.10: Trend in average nitrate concentrations in 1,105 common monitoring points between the previous period 2012-2015 and the current reporting period 2016-2019[9].

More than 50% of monitoring points show stable nitrate trends between the two periods, 31.3 % of the monitoring points are decreasing, whereas 18.3 % are increasing. Both increasing and decreasing trends can be found all over the country. The table gives no information on the level of nitrate in groundwater with increasing nitrate content or the age of the groundwater, which could help to explain the increasing trends, in spite of 30 years of action plans.

To compare nitrate in oxic groundwater and N loss from agriculture, groundwater age is determined by the use of the CFC method. This method allows to determine groundwater age with an accuracy of about ±2 years, and thereby direct comparison of amount of nitrate and time of groundwater recharge instead of time of sampling is possible.[19]

[19] Hansen, B., Thorling, L., Schullehner, J., Termansen, M. & Dalgaard, T., 2017: Groundwater nitrate response to sustainable nitrogen management. Scientific Reports, 7, 8566. DOI: 10.1038/s41598-017-07147-2.

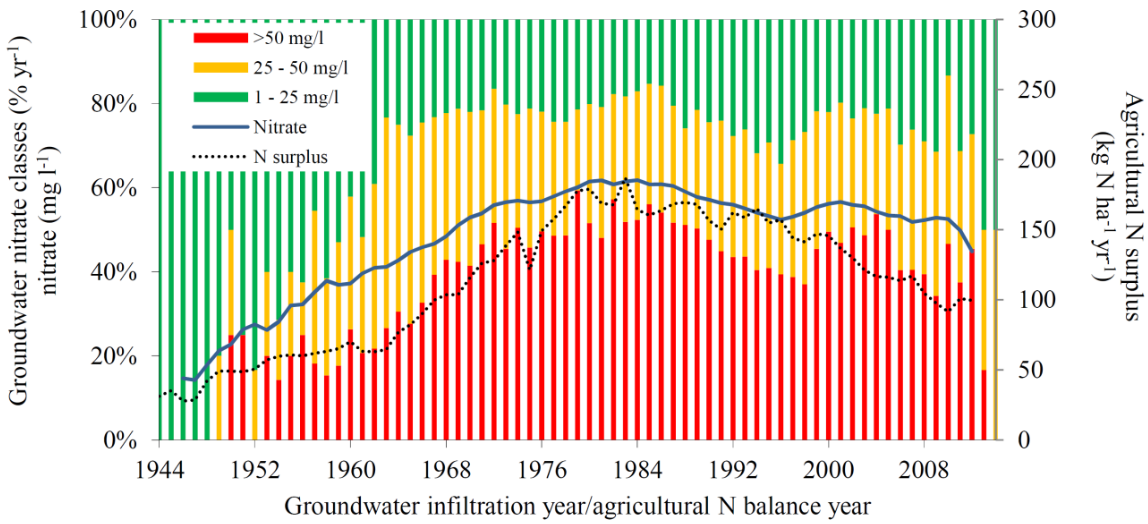


Figure 3.11: *Concentrations of nitrate in oxic groundwater (5-years moving average) as a function of infiltration year for dated groundwater, and nitrogen surplus in agriculture. Nitrate concentration classes are also shown for the intervals: >50 mg/l, 25-50 mg/l, and 1-25 mg/l. A total of 5,506 nitrate samples from 340 oxic monitoring points are shown[20].*

Figure 3.11 shows increasing nitrate concentrations in groundwater, recharged in the period from 1945 to 1985. This is probably due to the development of the Danish agriculture with an increasing agricultural input of nitrate in that period. In groundwater recharged after 1985, a decreasing trend in the nitrate concentrations in oxic groundwater can be seen.[21]

To support the trend reversal shown in figure 3.10, nitrate concentrations and their development have been investigated with a linear regression analysis of nitrate time series from individual monitoring points. A nitrate trend is interpreted as increasing if the slope coefficient of the regression line through the monitoring points is positive, and decreasing if it is negative. Figure 3.11 shows the accumulated result of the 303 calculated nitrate trends for the individual monitoring points distributed over the four periods with both statistically significant and non-significant trends at a 95% confidence

[20] Hansen, B. & Larsen, F. 2016: Faglig vurdering af nitratpåvirkningen af iltet grundvand ved udfasning af normreduktionen for kvælstof i 2016-18. Danmarks og Grønlands Geologiske Undersøgelse Rapport. 2016/04. GEUS.

[21] Hansen, B., Dalgaard, T., Thorling, L., Sørensen, B., Erlandsen, M., 2012: Regional analysis of groundwater nitrate concentrations and trends in Denmark in regard to agricultural influence. Biogeosciendes Disucssion paper, 9, 5321-5346, 2012. http://www.bioge-osciences-discuss.net/9/5321/2012/bgd-9-5321-2012.html

level. Trends of the 303 monitoring points show a clear trend towards a declining nitrate content in oxic groundwater.[22]

Overall there is a clear trend of a reversal at the beginning of the 1980s towards a more sustainable agricultural N management and a decline of N-surplus. The handling, storage, applying of manure and other fertilizers have improved and reduce the risk of environmental accidents. There is also an efficient control of compliance with the rules. In summary, one can identify a clear trend towards a declining nitrate content in oxic groundwater. However, the environmental and human health thresholds are still exceeded in some locations. Groundwater protection is of fundamental global importance, and this calls for further development of environmentally and economically sustainable N management in agriculture.

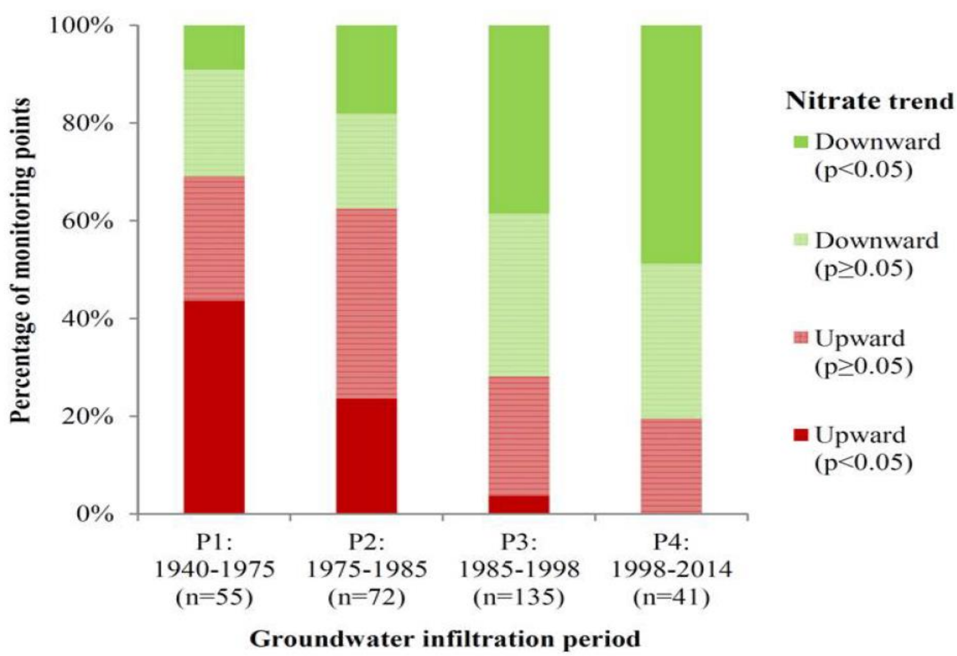


Figure 3.12: ***National groundwater monitoring network "GRUMO": Oxic groundwater only: nitrate trends in 303 monitoring points in oxic groundwater for 4 periods based on the year of groundwater formation. The analysis includes a total of 3,233 samples from 250 screens, where the time series cover at least 8 years. The numbers in brackets shoes the number of monitoring points. Both statistically significant and non-significant nitrate trends are shown at 95% confidence levels. The figure is based on data collected from 1988-2014 (Hansen et al., 2017**[23]**).***

---

[22] Hansen, B., Thorling, L., Dalgaard, T. og Erlandsen, M., 2011: Trend Reversal of Nitrate in Danish Goundwater – a Reflection of Agricultural Practices and Nitrogen Surpluses since 1950. Environmental Science and Technology, vol. 45 nr.

[23] Hansen, B., Thorling, L., Schullehner, J., Termansen, M. & Dalgaard, T., 2017: Groundwater nitrate response to sustainable nitrogen management. Scientific Reports, 7, 8566. DOI: 10.1038/s41598-017-07147-2.

4. GOOD PRACTICE EXAMPLE 2: GROUNDWATER CATCHMENT SCHEMES IN ENGLAND

Introduction

Within England about a third of the drinking water comes from groundwater abstractions. These public and private drinking water supply abstractions are increasingly under threat from rising trends in groundwater pollutant concentrations. Traditionally these pollutants were removed from raw groundwater using expensive treatment solutions before the water went into drinking water supply. Over the last two decades water companies in England have made increasing use of catchment schemes to reduce the need for treatment. Catchment schemes aim to reduce the pollutant load lost to surface water and groundwater by improving land use management practices.

This push towards catchment schemes was partly driven through the legislation in the Water Framework Directive (WFD). Article 7.3 of WFD specifies that *'Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water'*. Therefore, in Drinking Water Protected Areas WFD Article 7.3 promotes compliance with the Drinking Water Directive through preventative catchment-based actions. The competent authorities for the WFD had to achieve this compliance with this requirement by 2015, and this requirement cannot be derogated. Within England, one of the ways this is delivered is through catchment schemes. Guidance has been issued to water companies to require them to make use of catchment schemes instead of increasing treatment.

This catchment scheme approach to managing the quality of raw water for potable use helps to reduce the concentration of pollutants in raw water and reduce the need for drinking water treatment. The approach is more sustainable, less energy intensive and cheaper for water companies. It does however require water companies to work closely with land managers. This chapter explores the use of catchments schemes in England.

The problem

Many of the groundwater abstractions in England that are used for drinking water supply are in rural areas making these supplies vulnerable to contamination from agricultural pollutants, including pesticides and nitrate from fertilisers. Within England, nitrate concentrations in groundwater are continuing to rise slowly. Pollutant transit times through the soil and unsaturated zone to groundwater can be long in England depending on the geology. There may therefore be an historic component that contributes to the observed trends in some locations. In 2015, 25.5% of Groundwater bodies in England had failed the Water Framework Directive trends test due to increasing nitrate concentrations and by 2019 this figure had gone up to 26.9%. Water companies cannot put water into supply that is above specific drinking water standards (e.g. 50 mg/l nitrate and 0.1 ug/l pesticides). Therefore, they must either treat the water using an advanced water treatment solution, blend with other less polluted water, temporarily or permanently close the abstraction and seek an alternative water source, use catchment-based solutions to reduce pollution or a combination of these options. For example, a combination of approaches could be treatment through blending and / or chemical treatment along with catchment schemes to ensure that treatment is only required in the short term.

A key operational concern for water companies is spikes in concentrations of contaminants, which may cause failures of Drinking Water Standards. These spikes are operationally difficult to manage for water companies. They often result from extreme weather events, such as intense rainfall, and seasonally high groundwater levels which may become more common with climate change. Catchment schemes can be part of the solution to manage the impact of spikes and the resilience of the land to extreme weather.

<u>The advance treatment solution</u>

Advanced treatment solutions to removed pollutants from raw groundwater before the water goes into supply have been commonly used throughout England for many decades. These systems are very reliable and enable water companies to have a high degree of confidence when complying with drinking water standards. They include reverse osmosis and ion exchange to remove nitrate, and granular activated carbon filtration to remove pesticides. There are some downsides, however. Firstly, they are very expensive to install. For example, a plant to remove nitrate may cost £8m to install and many more millions to run over its lifetime. These systems have a high demand for energy and natural resources and therefore have a large carbon footprint. Also, the supply of drinking water treatment chemicals has been under pressure in recent years and this can lead to operational difficulties. In some cases, they also produce a contaminated waste stream that needs to be disposed of. In England the cost of these systems is passed on to water consumers through increased water bills. Blending of lower quality groundwater with higher quality groundwater is also used extensively in England where possible as a cheaper option to advanced treatment. This option depends on having a low nitrate source and an engineered network to connect sources for blending. At some low nitrate sources, concentrations are rising, which means that blending capacity is reduced leading to the need for advanced treatment in the medium to long term.

Catchment schemes can provide an alternative to or complement advanced treatment solutions and help to prolong the capacity for blending. Over the long term they can deliver similar outcomes to treatment at a lower cost, whilst also delivering other wider environmental benefits. Securing long term catchment management can be challenging for water companies as landowners may not be willing to agree to long-term actions and so there may be less certainty for the companies compared to treatment. With little control over the land or ownership change it can be hard to secure long-term land use/practice change. However, by demonstrating alternative good practice it is possible to 'change hearts and minds' which can have a lasting impact e.g. system change which can in time be self-funding. The key is in reducing/lopping pollutant peaks and in time reducing the baseline so seasonal peaks can be accommodated.

The catchment schemes solution

Catchments schemes involve working in partnership with landowners within the catchment of the abstraction to put in place measures to reduce surface water and groundwater pollutant loading and meet the water quality objective at the abstraction point. These schemes are a combination of voluntary, regulatory, and financial measures.

Voluntary measures could include targeted advice to farmers to help them reduce nutrient or pesticide losses from their fields. This could be by sharing best practice information or support in completing applications for existing (state funded) infrastructure improvement grants. Voluntary measures are typically delivered through catchment officers, who are individuals with knowledge of farming systems and the environment. In England these are mainly funded either via the Government (Catchment Sensitive Farming scheme) or water companies (catchment officer).

Regulatory measures could include the local environmental regulator visiting farms to inspect records and carry out checks to review compliance with existing water protection legislation and guidance. If non-compliance is observed then this could result in a written or verbal warning letter. If serious repeat non-compliances are observed then these could result in financial penalty and/or prosecution. In England regulatory measures are delivered by the Environment Agency.

Case study 1 – The Poole Harbour Nutrient Management Scheme

Poole Harbour in Southern England has a catchment area of approximately 800km^2. Its soils and groundwater are vulnerable to leaching from nutrients and chemicals. The harbour itself is internationally important and has the highest levels of protection for its wildlife.

From the 1960's, concentrations of inorganic nitrogen (N), (mainly nitrate) entering the harbour from rivers have increased. Excessive growth of green seaweeds, forming "macroalgal mats" have been seen, smothering native plants and intertidal creatures, impacting bird feeding areas. This has had knock on effects on the harbour's marine ecology, reducing suitable habitat and food availability for birds, some of which have declined greatly in numbers.

These impacts are attributed to high levels of nitrogen (and possibly phosphorus) entering the catchment. Detailed catchment modelling has been carried out to determine the maximum allowable level of nutrient input into the catchment to ensure that the ecology is protected.

Figure 4.1: Macroalgal mats caused by excess nutrients in Poole Harbour; Source: Natural England

Based on this modelling the Environment Agency has set a nutrient emission limit for each sector. For the agricultural sector the emission limit has been set as a whole farm emission limit. Farmers must calculate their whole farm nutrient balance each year and report this information to the EA or an independent 3rd party. The EA have left it for farmers to decide how they will achieve these farm limits. This will allow each sector to find the solutions which meet their business model and encourage innovation and efficiency, including between sectors. If the nutrient limits are not met a statutory Water Protection Zone may be required, which may lead to more formal targets and standards. For more information on this scheme please use this link:
About the scheme - Poole Harbour Nutrient Management Scheme (pooleharbournitrates.org.uk)

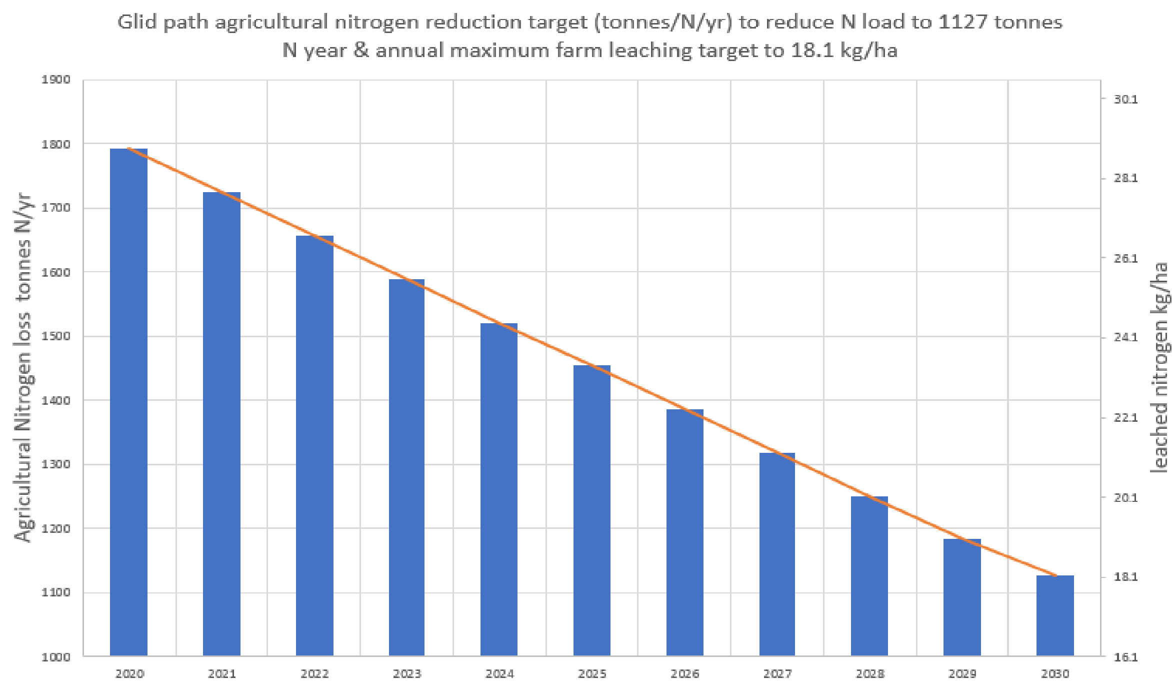


Fig. 4.2: Glid path agricultural nitrogen reduction target (Source: Environment Agency)

Financial incentive measures are typically used when the farmer or landowner is already meeting good practice farming standards, but this is still not delivering the outcome required. This is because good farming practice standards are often not sufficiently robust to completely protect the water environment. In terms of groundwater loads, current practice is often contributing to a historic load which in combination exceeds the water quality standards. Under these circumstances it may be cost-beneficial to pay the farmer or landowner to go beyond good practice. This could include measures such as reverting cultivated land to lower nutrient input management such as natural habitat (arable reversion) or growing cover crops to capture excess nitrate in soil in periods when soils may be bare between main crops. If a farmer agreed to undertake such a measure, they could be compensated for any income that they may lose through changing how they manage the land. In some cases, the change in management style may help to improve income for example a change to organic or regenerative farming and in these instances financial incentives can be used to bridge the transition in system change. Financial incentives are either provided by Government, for example through grant schemes to improve farming infrastructure such as slurry lagoons, or through water companies or other private companies with services impacted by land use practices.

Case study 2 - Cambridge Water and Affinity Water (England, UK), EnTrade reverse auction scheme

Reference: https://www.cambridge-water.co.uk/environment/catchment-management/en-trade

One leading measure for reducing nitrate leaching to groundwater is winter cover crops. There is however a cost to cover cropping that is not immediately compensated by main crop yield increases. This cost prevents farmers from more widely adopting the measure despite opportunity, with many fields instead left as bare overwinter stubbles. With widespread opportunity for implementation, a reverse auction was used via the EnTrade environmental market platform to allocate Water Company funding, and efficiently scale the uptake of the measure.

What is a reverse auction?

The aim of the reverse auction is to optimise nitrogen retention in the field while also aiming to achieve a fair price for growers. It's the reverse of a normal auction. Farmers bid the price that they are willing to be paid to grow an area of cover crop. A dial indicates where an individual's bid stands in comparison to other bids. This can be used to help adjust and edit bids at any time before the auction closes.

What makes a competitive bid?

When a bid is submitted, the EnTrade platform determines the nitrate saving of the crop choice and how cost effective the bid is. This determines each bidder's standing in the auction. To have a successful bid, it needs to be competitively priced. If a bid becomes uncompetitive, the bidder is notified. Bids can be adjusted multiple times before the auction closes.

Why implement cover crops?

The primary aim of the scheme is to work with farmers to protect water quality by growing cover crops in order to capture excess nitrates in soils, which may have otherwise leached into rivers and groundwater. Cover crops also help to improve soil structure, protect soil from erosion and can benefit farmland wildlife, such as pollinators. Through the 2020 EnTrade scheme 36,000 kg of nitrogen was saved by the introduction of cover crops across 800 acres.

5. GOOD PRACTICE EXAMPLE 3: WATER PROTECTION ZONES AND COOPERATION AGREEMENTS IN HESSENN / GERMANY

For 29 out of 127 groundwater bodies (gwb) within the State of Hessen the chemical status is classified as "poor". Groundwater pressures attributable to nitrogen compounds remain the main reason why Hessian groundwater bodies exhibit “poor“ chemical status. Threshold values for nitrate (20 gwb), sulphate (4 gwb), ammonium (6 gwb), pesticides (6 gwb), orthophosphate (4 gwb) and/or chloride (6 gwb) were exceeded.

The main driver for nitrate pollutions of aquifers are nitrogen losses from intensive agricultural production. Considerable efforts have been devoted to prevent deterioration of status, reverse any significant and sustained upward trends in nitrate concentrations in groundwater, and progressively reduce pollution. In Hessen, different instruments are used for the protection of ground water quality and for the improvement of agricultural practices, with the aim to minimize nitrogen leaching from fertilization. For drinking water resources, the concept of protection areas is applied since more than 60 years.

According to sec. 51 of the Federal Water Act (WHG), **water protection areas** (*Wasserschutzgebiete*, WSG) can be established in order to protect bodies of water from adverse effects, especially in the interest of current or future public water supply. Requirements, prohibitions and limitations of land use are laid down for each water protection area in a statutory ordinance which in Hessen is issued by the higher water authority *(Regierungspräsidium)*. Depending on the potential risk of raw water pollution, the catchment area is divided into different water protection zones (I, II and III or IIIA and IIIB), for which specific requirements or prohibitions are defined. This also includes regulations of agricultural land use. Here, the Hessian water law (sec. 33.2 HWG) provides for voluntary cooperation agreements between farmers and water suppliers, which should take priority over the agriculture-related bans and requirements of the statutory ordinance.

In Hessen, more than 1,600 drinking water protection areas (WSG) are established, which cover about 30 % of the area of this state. The following map shows the WSG in Hessen and their respective outer zones (yellow or orange) and inner zones (blue). “Zone I” is the immediate neighbourhood of the well or source and thus not visible on the map.

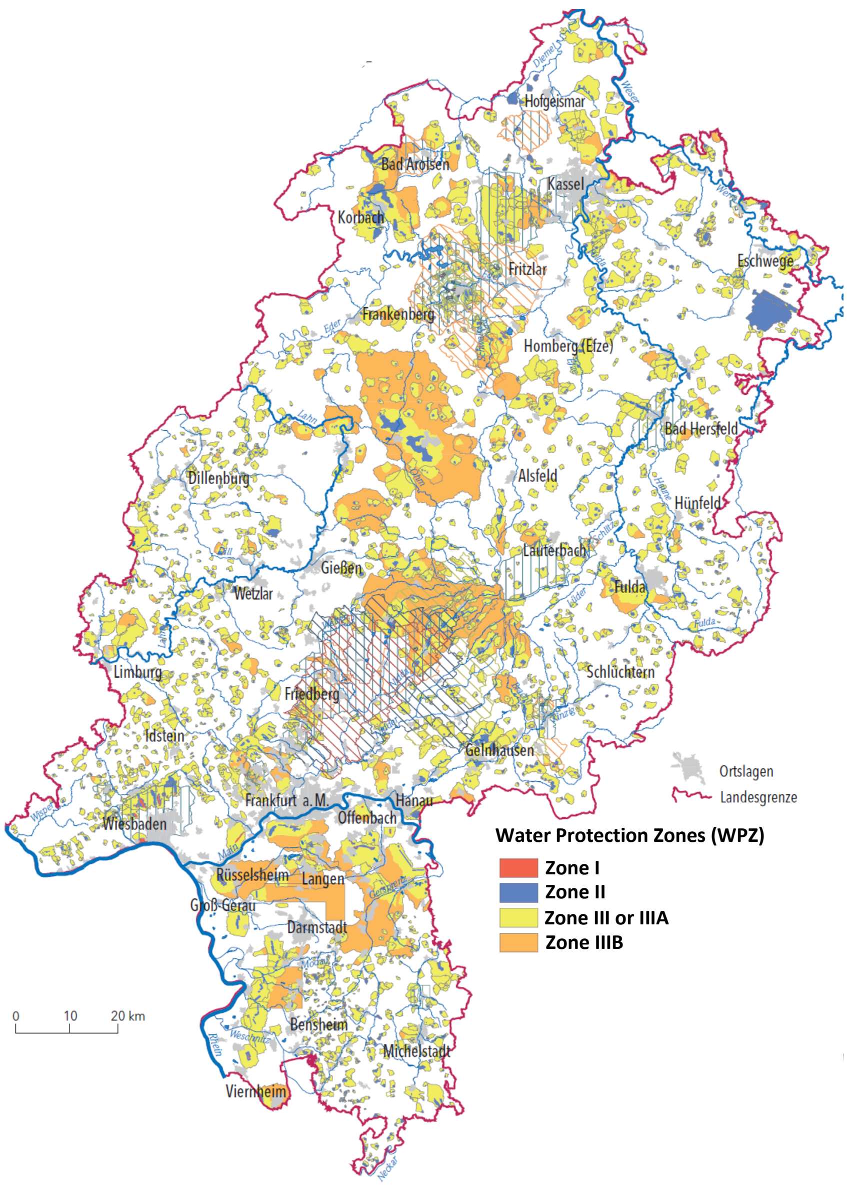


Fig. 5.1: Water protection areas in Hessen 2021 (Source: HLNUG / HMUKLV)

Since the early 1990s, water suppliers have entered into **cooperation agreements** with local farmers particularly in water protection areas with a nitrate concentration above 25 mg/l (WSG class C). By now, such agreements exist in about 10 % of the water protection areas in Hessen. They set out rules for land management adapted to local conditions, but also contain provisions for cooperation and possible compensation payments. The cooperation agreement is a voluntary contract under private law between the water supply company and those entitled to use the land in the water protection area for agricultural purposes. Nevertheless, if the agreement has been approved by the higher water authority, its provisions replace the agricultural regulations of the water protection area ordinance for the land of the farmers who signed the contract. The aim of a cooperation agreement is to reduce the inputs (e.g. nitrate) into the groundwater or to maintain an already groundwater-friendly agricultural use in the area. The advantage of this mechanism is that farmers feel more committed to the agreement they have signed, that the rules are adapted to local circumstances and that it is possible to react more flexibly to changing conditions.

WSG cooperations which involve on-the-ground **agricultural advice** financed by the water supplier have proven to be particularly successful. This advice includes in particular:

- Measuring and discussing the amount of plant-available nitrogen in the soil (N_{min}) in spring;
- Fertilizer recommendations calculated from this, which are based on mostly precise determination of the N_{min} and are usually significantly lower than the upper limit allowed by the German Fertilizer Ordinance if the harvest is good;
- Inclusion of subsequent deliveries of organic fertilizers, tillage measures;
- Advice accompanying the vegetation, which includes current topics such as the weather, plant growth, possible mineralization (release of nitrogen from the soil);
- Advice on whether a third application is necessary for fertilizer-intensive crops such as spring wheat and, if so, how much;
- Advice on post-harvest management;
- Prevention of leaching of excess nitrogen through advice/regulations on the cultivation of catch crops, greening between rows, cultivation of winter crops;
- Discussing results of autumn N_{min} measurements.

The advisory measures are based on the nitrate discharge risk class, which was precisely defined when the water protection area was determined (5 NAG classes from very high = 1 via high = 2, medium = 3, low = 4 to very low = 5).

Fig. 5.2: Water protection in cooperation with agriculture – on-site visit and machine demonstration (Source: Schnittstelle Boden)

The cooperation agreements can cover the following **subject areas** with corresponding prohibitions/requirements:

- Needs-based fertilization,
- Cover crop cultivation, crop rotation design,
- Agri-environmental measures such as the Hessian subsidy program HALM,
- Embargo periods,
- Set-aside,
- Water-protecting implementation of ploughing-up / soil cultivation measures,
- Grazing,
- Storage of mineral and organic fertilizers,
- Use of plant protection products / pesticides,
- Afforestation / forest clearing,
- Cultivation of special crops (vegetable cultivation and/or viticulture).

In addition, arrangements are usually made on the following topics:

- Measurements for controlling (N_{min}),
- Rights of use / rights of access of the consultants, samplers, water suppliers,
- Management and handling of field files,
- Compensation payments from the water supplier for measures that go beyond regulatory law,
- Sanctions for the enforcement of the cooperation agreement,
- Working group to support and further develop the cooperation.

The most important criterion for the assessment of groundwater status is the nitrate concentration in groundwater monitoring stations. Due to the effects of retention time on nitrate concentrations - groundwater extracted from deep wells has inherently lower nitrate concentrations than from shallow wells - it is necessary to measure not only NO_3 but also more parameters like **N_{min}** (plant available mineralized nitrogen) to be analysed in different soil horizons. The determined N_{min} values are used for controlling the advice. For this purpose, soil samples are taken in the soil horizons (0-30 cm, 30-60 cm, 60-90 cm) and analysed:

- In **spring**, the plot-related determined N_{min} provides information about how much nitrogen is already available in the soil.

  - These nitrogen contents come, among other things, from surpluses left in autumn, mineralization in the soil through tillage, fertilization through organic fertilizers, which usually only release nitrogen 6-8 weeks after incorporation.
  - Taking into account the nitrogen already present, it is usually possible to recommend significantly lower fertilizer doses than the maximum permitted by the Fertilizer Ordinance. Nevertheless, a good harvest can be achieved.
  - The impact on mitigation by leaching can be estimated based on the N_{min} data from last fall.

- During the **vegetation period**, the **N_{min}** provides information as to whether further fertilizer applications are required or not, and if so, at what level.

- The **autumn N_{min}** provides information as to whether the fertilizer application via plant growth and, if applicable, cover crops was well absorbed and whether it was sufficient, i.e. not set too high.

- The **post-harvest N_{min}** indicates whether the available nitrogen levels are so high that there is a risk of leaching in winter, which should be countered by cultivating catch crops.

Assuming that all available nitrogen from the root zone in the soil is leached into the groundwater, the orientation value of N_{min} in the soil is between 30 and 50 kg/ha N, depending on the amount of percolation water (mm). It can be assumed that N_{min} values of more than 50 kg/ha N lead to nitrate concentrations of more than 50 mg/l in the groundwater.

Some WSG cooperation agreements reward low autumn N_{min} values with additional compensation payments. This subsidy can be viewed as a kind of "meta-measure" reflecting the impact of many different actions and operations.

The water suppliers balance all measures that go beyond regulatory law (fertilizer rights) with compensation payments.

<u>Good practice example:</u>

Water Protection Area (WPA) Großer Brunnen, Bad Wildungen

Size of WPA: 730 ha; Geology: one third red sandstone, Permian limestone, loess

Since 1989 nitrate concentrations of groundwater in the drinking water well are monitored monthly. Nitrogen surplus for each area inside the WPA (input-output balancing of nitrogen) is balanced annually. Furthermore, soil samples (0-30 cm, 30-60 cm, 60-90 cm) are taken twice per year to analyse the N_{min} concentrations of all areas before and after the vegetation period. Additionally, at the end of the vegetation period N_{min} concentrations on representative demonstration areas are analysed to determine the residual nitrogen in the soil between 0 and 90 cm depth. Along with these monitoring measures, farmers are offered a comprehensive range of consulting services to fertilize in an environmentally sound way.

Cooperation activities between water suppliers (municipality) and farmers must integrate state-of-the-art-rules on farming management to protect groundwater.

- Groundwater protection farming requires mapping of the soil characteristics of each area and the risk level of nitrate leaching;
- Limitation of nitrogen fertilization (mineral, organic);
- Groundwater protection advice to farmers;
- State-of-the art storage of liquid manure (slurry), possibly with financial support from the state or the water supply company;
- N_{min}-Sampling and recommendation for fertilizing;
- Input-output balancing for each lot;
- Mandatory intercropping.

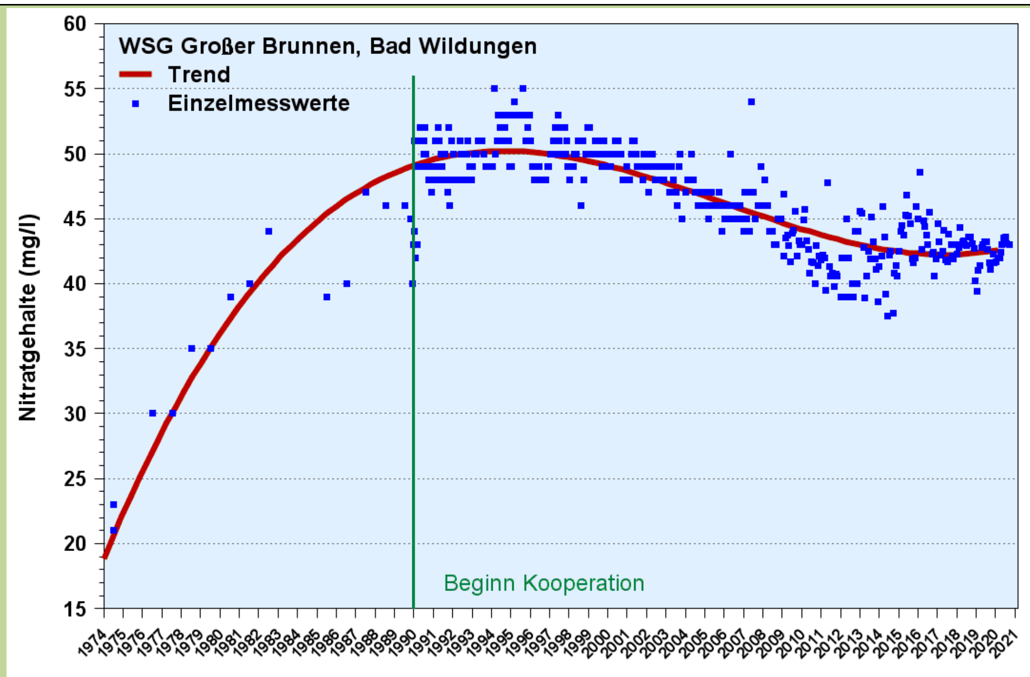


Fig. 5.3:: Nitrate concentrations drinking water well „Großer Brunnen“ Bad Wildungen (Source: Schnittstelle Boden)

It has become apparent that the described WSG cooperations are able to reduce groundwater pollution significantly only in combination with good communication between farmers, water utilities and water authorities as well as comprehensive regulations around water quality protection. As a result of Germany's conviction for inadequate implementation of the EU Nitrate Directive in 2018, fertilizer legislation has been extensively revised accompanied by new obligations particularly in nitrate-polluted areas, such as:

- the prohibition of the application of fertilizers in the autumn and winter months;
- the prohibition of fertilization on frozen soil;
- the increase of the distances when fertilizing along open water bodies, and
- an obligation to keep records of fertilizer requirements.

With the amendment of the national and regional fertilizer legislation, many more new requirements came into force that will have a positive impact on the reduction of nutrient inputs from agriculture into surface waters and groundwater. The extent to which this will improve the chemical status of the groundwater bodies is still subject to some uncertainty, as these measures were not yet established during the last management period (2015 – 2021) and their effect could therefore not yet be assessed.

6. GOOD PRACTICE EXAMPLE 4: MITIGATION MEASURES TO REDUCE PESTICIDE POLLUTION OF GROUNDWATER IN LOMBARDY / ITALY

In the Lombardy region, the use of pesticides, and therefore their spreading to the field, is regulated by the Regional Agricultural Plan PAR,

Written by colleagues from the Lombardy region, General Agriculture Directorate, regional phytosanitary service.

The PAR contributes to the pursuit of common objectives between those set out in Directive 2009/128 / EC and those set out in Directives 2000/60 / EC (framework directive on water), 92/43 / EEC (directive for the conservation of natural habitats and semi-natural and wild flora and fauna), 2009/147 / EC (directive for the conservation of wild birds).

in Lombardy, the regional decree of 21 December 2021 represents the guidelines for the implementation of the National Action Plan for the use of Plant Protection Products (PAN), and establishes that the professionals who can use plant protection products must follow basic training courses and refresher courses, preparatory to the release of the necessary qualifications. The courses include a mandatory final exam which must be successfully passed to obtain the qualification. The equipment used for spreading phytosanitary products must be certified, and pass the functional check and calibration. This check is carried out exclusively by accredited subjects.

In particular for the implementation of the PAR, the following priority areas are identified:

- Corn, due to the significant area affected by this cereal in function of the strategic role it plays as a staple food of the zootechnical system;
- Rice, due to the territorial concentration and the particular specificity of the cultivation environment;
- Vine, due to the importance of the surface covered and the high number of treatments required for phytoiatric defense;
- the use of plant protection products in an extra-agricultural environment with particular reference to Glyphosate.

Mitigation measures activated for water protection contained in PAR

Active Substance	Expected Mitigation	Area of Application
Bentazon	Prohibition, throughout the region, to use the active substance for rice weeding programs	Whole Regional Territory
	Annually the use of the active substance on a maximum of 50% of the company's UAA (usable agricultural area)	Pavia Province
Glyphosate - AMPA	The use of the active substance on a maximum of 50% of the company's UAA (usable agricultural area) is allowed annually	Whole Regional Territory
	The use of the active substance on a maximum of 50% of the company's UAA is allowed annually, for rice farms in the province of Pavia, in crodo rice containment programs, in association with the false sowing technique	Rice cultivation
	The use of the active substance on a maximum of 70% of the company's UAA is allowed annually, exclusively for companies that adhere to the operation of the Rural Development Program relating to conservation agriculture	Whole Regional Territory
Metolachlor	The use of phytosanitary products containing Metolachlor S-Metolachlor at most on 70% of the company's UAA is allowed annually, represented by the sum of the crops on which the	Cremona, Mantova, Brescia

S-Metola-chlor	active substance is authorized, regardless of the time in which they are distributed and the concentration with which the substance is active is present in the formulation	
Terbutilazina	The use of plant protection products containing Terbuthylazine at a maximum of 70% of the company's UAA is allowed annually, represented by the sum of the crops on which the active substance is authorized, regardless of the time in which they are distributed and the concentration with which the active substance is present. in the formulation	Lodi, Cremona, Bergamo, Brescia

Trends in phytosanitary substances in the Lombardy Region

- **Bentazon**, the maps show an objective improvement and confirm the effectiveness of the mitigations adopted for the active substance, it is however considered appropriate, for the precautionary principle, to confirm the measures adopted with the DGR 1376/2019;
- **Glyphosate - AMPA**, in general at the regional level the situation appears, albeit minimal, slightly improving with the exception of the rice-growing area of the province of Pavia where there is a worsening of the situation, it is therefore considered necessary to confirm the measures adopted with DGR 1376 / 2019 extending them also to the rice area. The areas in which the fight against M. graminicola is carried out with the use of rice as a trap plant are excluded from the mitigation count;
- **Metolachlor - S Metolachlor**, the maps show an objective improvement and confirm the goodness of the mitigations adopted for the active substance, it is considered appropriate, for the precautionary principle, to confirm the measures adopted with the DGR 1376/2019;
- **Terbuthylazine and Terbutylazine + metabolites**, the maps show an objective improvement and confirm the goodness of the mitigations adopted for the active substance, it is considered appropriate, for the precautionary principle, to confirm the measures adopted with the DGR 1376/2019, also in consideration of the future restrictions on the use of plant protection products containing TBZ introduced after June 14, 2022.

How to inform operators and how to carry out checks on the application of the standards

- To inform operators (agropharmaceutical companies and farmers), meetings were organized on the territory and communications on the site of the regional phytosanitary service. All operators must undergo mandatory training meetings for the use of the substances in question.
- The authorities informed the association representing the national companies producing agropharmaceuticals (Agrofarma) and all companies holding authorizations of phytosanitary products, which therefore were aware of the mitigation measures and transferred their knowledge in turn to the resellers.
- Controls by the body in charge take place indirectly, through the analysis of electronic registers (containing personal information on the farm, the date of the treatment carried out, the product used, the quantity used and the surface treated) relating to phytosanitary treatments carried out by agricultural companies. The electronic register is operated and the controls performed by the General Directorate of Agriculture for the Lombardy Region.
- The GD of Agriculture (Regional Payment Office – OPR) carries out cross-compliance checks regarding the constraints imposed by the EU Common Agricultural Policy, e.g. on nitrates as well as dangerous and phytosanitary substances. In case of non-compliance the regional grants to the respective operators will be reduced. Other sanctions may be considered for the next plans. The first goal was to try to reduce the impacts of pesticides on the territory.

How to read the maps (VandA App)

The colours represent the deviation from the worst case; values assigned to a percentage:

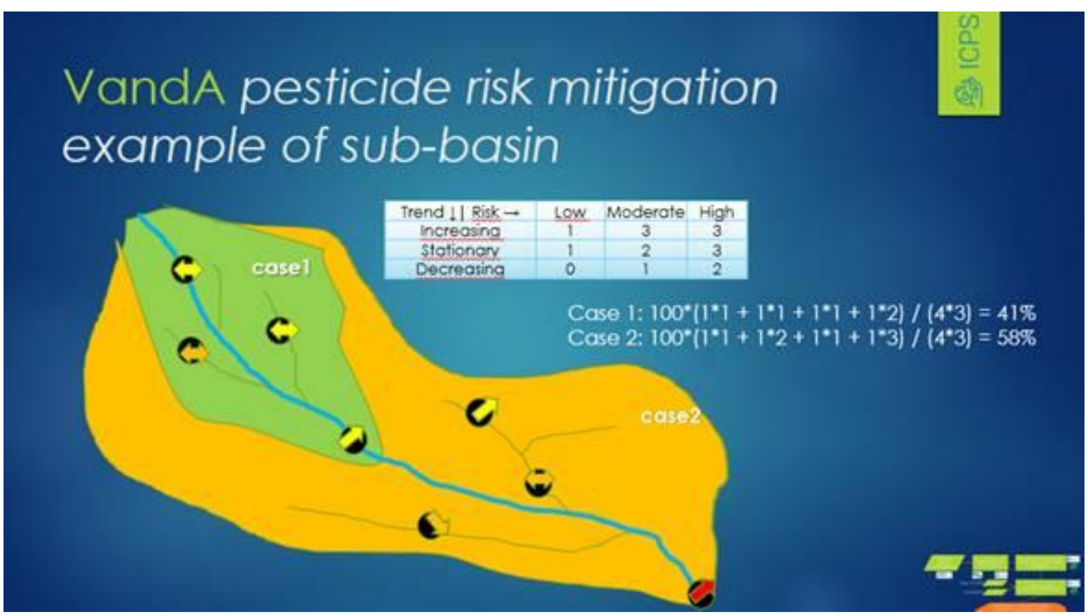
0 distance from the worst case, 1 case very similar to the worst case.

VandA Application works with weights that are assigned to all the various stations based on the time trend and the risk class they fall into. The temporal trend is evaluated by comparing the data, x station, of a two-year period, aggregated by maximum, 95th percentile or average, with those of the following two years. While the risk class is assigned in the last 3 years taken into consideration, how many times has the mec / pnec ratio been exceeded.

Depending on these two factors, there is a matrix of weights to refer to divided by low -medium - high risk class and decreasing – steady - increasing time trend.

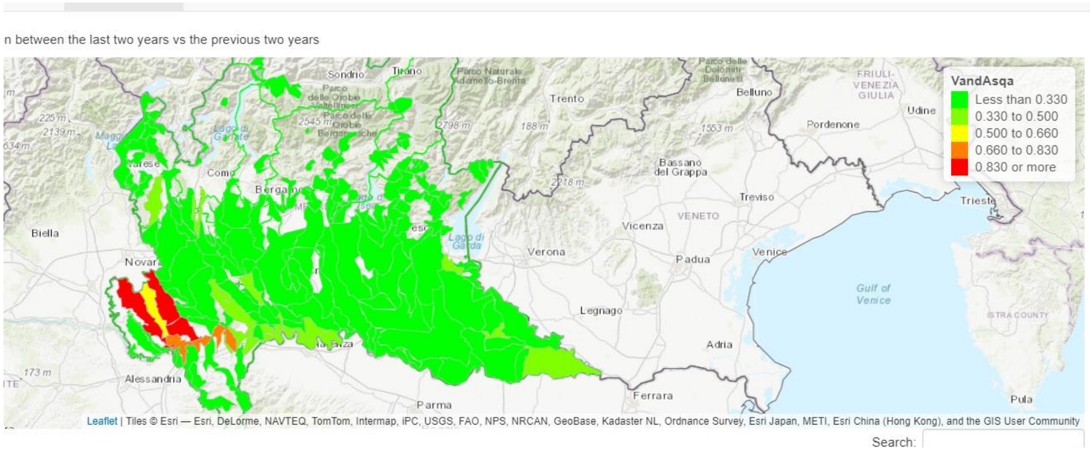
After that, for each basin we proceed with this methodology: all the weights of the stations present in the reference hydrographic basin are added, and the result obtained is compared with the worst case, i.e. the case in which all the stations included in the hydrographic basin, have the greatest weight, i.e. increasing time trend and high risk class.

Example: Assume that the number 5 has been chosen as the value of the weight scale (because the weight scale is customizable), and there are 3 monitoring stations in the catchment area, and that the sum of the weights of the stations gives 6 (station 1x weight = 1 + 1x3 + 1x2), this value should be compared with 15 or 3 stations x 5 maximum weight and therefore 6/15 = 0.4 or 40% of the worst case saturation and areal or catchment area would take on a greenish colour.

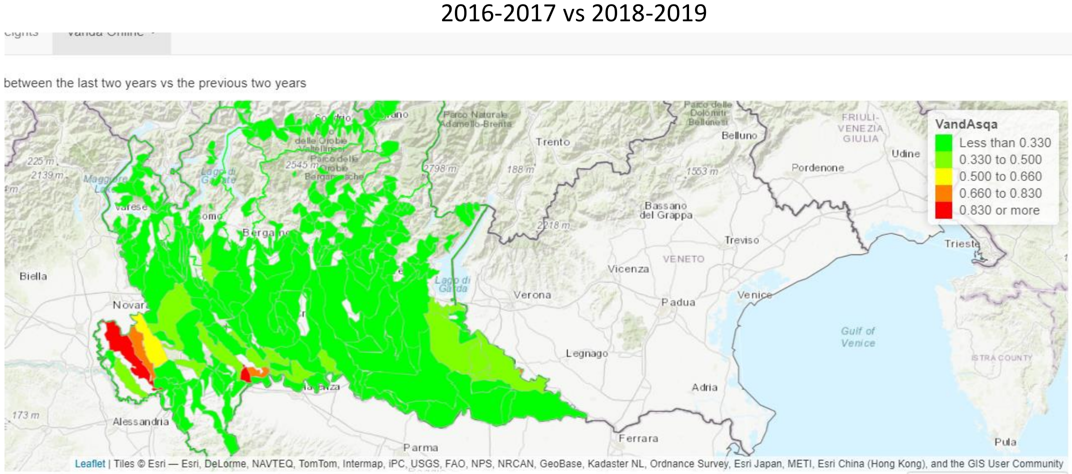


Bentazon

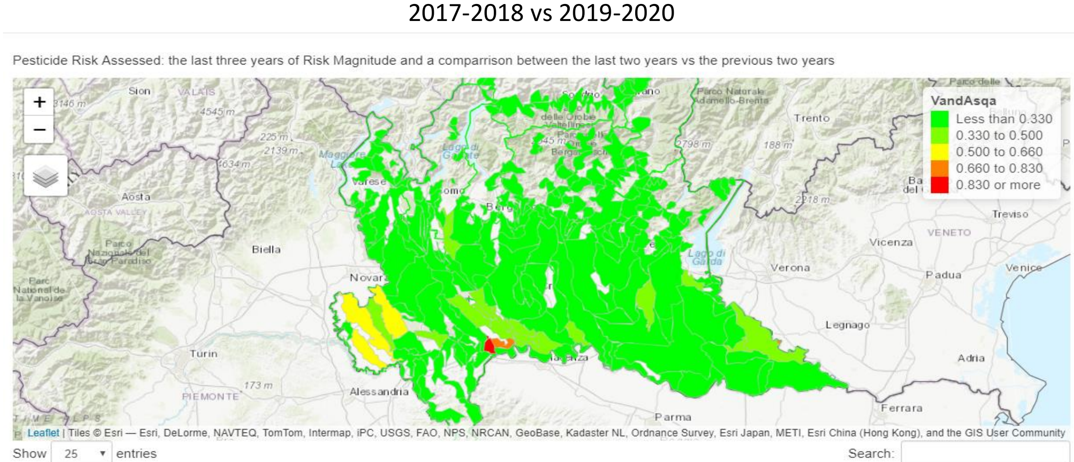
2013-2014 vs 2015-2016



2016-2017 vs 2018-2019

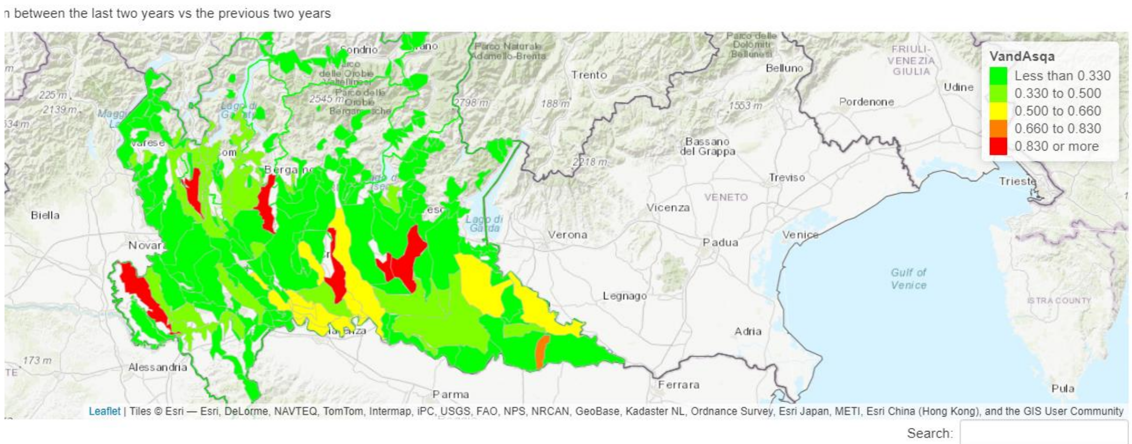


2017-2018 vs 2019-2020

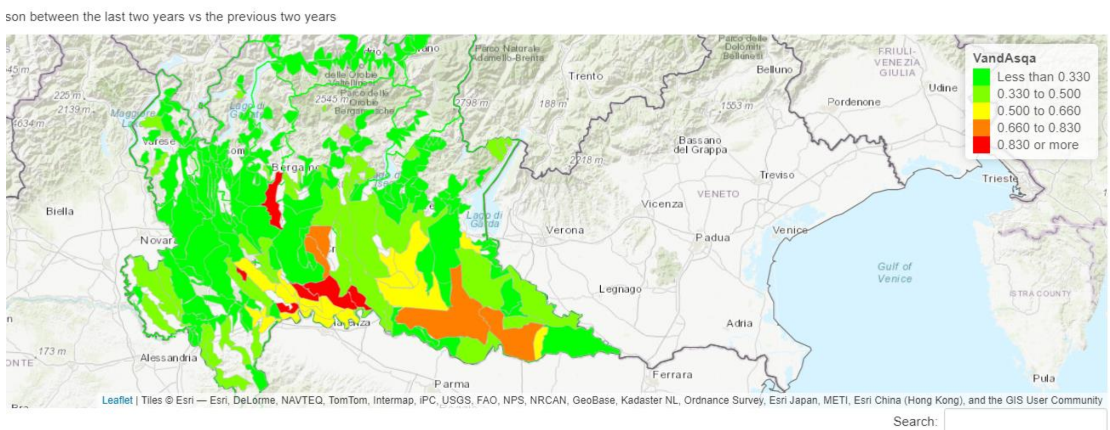


Metolachlor/S Metolachlor

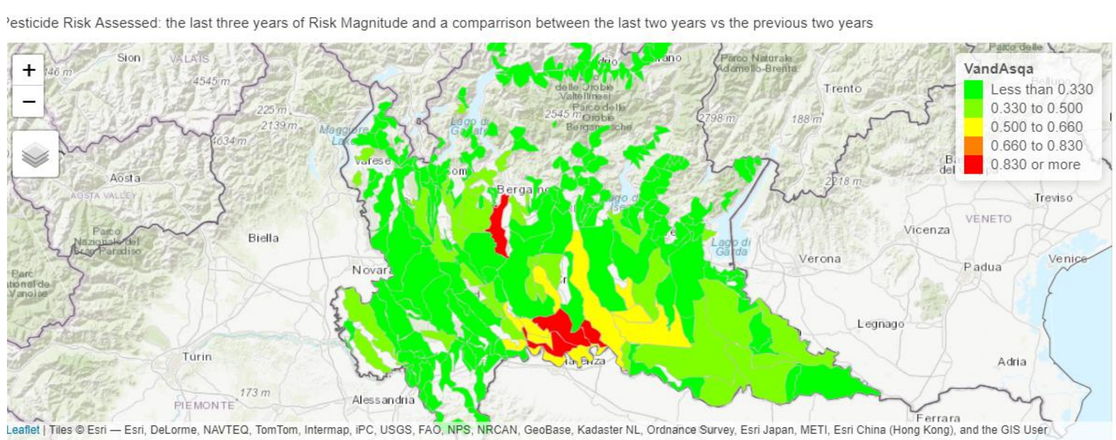
2013-2014 vs 2015-2016



2016-2017 vs 2018-2019



2017-2018 vs 2019-2020



Maps were obtained thanks to the VandA application, created by colleagues from ICPS, international center for pesticides and health risk prevention.

In the Lombardy Region, the use of the aforementioned mitigation measures has therefore made it possible, from 2015 (the year in which the measures were implemented) to date, to improve the situation relating to pesticide pollution in surface and groundwater.
From the reported trends, it can be assumed a continuously improving trend also for the next years of analysis.
The measures therefore appear to have been effective.

LINKS:

- PAN - https://www.reterurale.it/pan_fitosanitari
- PAR (Lombardy) - https://www.fitosanitario.regione.lombardia.it/wps/portal/site/sfr/protezione-delle-colture-e-del-verde/PAR
- VandA - https://www.icps.it/it/pubblicazioni/vanda-visualize-and-assess-a-tool-for-the-pesticide-risk-mitigation-in-surface-water/

7. GOOD PRACTICE EXAMPLE 5: GUIDING FARMERS IN THE CONTEXT OF THE NITRATES DIRECTIVE IN FLANDERS / BELGIUM

The Nitrates Directive

The Nitrates Directive (91/676/EEC) of 12 December 1991 concerns the protection of water against pollution caused by nitrates from agricultural sources. Through the designation of Nitrate Vulnerable zones (NVZ's) and Manure Action Plans translated into legislation and to be implemented by farmers, each of the European Member States have to tackle polluted waters or protect the waters at risk of pollution (i.e. surface waters, ground waters, estuaries, coastal and marine waters) in order to preserve overall water quality and biological life. The Manure Action Plans set rules to prevent nutrient losses into the environment - primarily of nitrogen (N) but also of phosphorus (P) - by limiting the period of fertilisation, the maximal use and the conditions of application of fertilisers, by imposing a minimum storage capacity for livestock manure on the farm, by rules on crop rotation, catch crops and soil winter cover etc.

Flanders has now its 6th Manure Action Plan (MAP 6), effective from 2019 through 2022, which has been translated in regional law with the Manure Decree ("*Mestdecreet*") giving implementation to the Nitrates Directive and also a result of the NEC Directive in terms of ammonia emissions while using nitrogen fertilisers.

Guiding farmers in Flanders: different steps

Flanders is organising guidance of farmers in the context of the Nitrates Directive. Part of the flanking policy of the Manure Decree, and supporting the goals of the Directive, farmer guiding has to be seen as on top of the legislation. A sequence of approaches has been adopted since 2007.

That guidance funded by the Ministry of Environment, is additional to other players (possibly) engaging in specific guidance and advice on fertilisation, crop advice and soil quality or on administrative obligations arising from the legislation, as done by laboratories, academic and technical research centres for agriculture, fruit and vegetable markets, food industry, accounting offices, … and is also on top of advice related to the European Common Agricultural Policy (CAP).

<u>Farm consultancy and sensitizing (BAS)</u>
The first step had been taken with "*Bedrijfsadvies*" or "farm consultancy and sensitizing", set up and executed by the VLM (Vlaamse Landmaatschappij) responsible for the implementation and the enforcement of the Manure Decree and also for policy monitoring and development in response to the

Nitrates Directive. Information sheets have been written and digital applications have been developed aiming at supporting the farmers in compulsory administrative tasks or aiming at increasing the farmers' insights in nutrient needs and nutrient-dynamics and allowing the use of farm-specific data and calculations. Farmers did not have to pay for group guiding or for individual guiding on the farm. Farmers could apply for counselling, or counselling was compulsory in case of poor farm environmental performance as known by the VLM. Guidance consisted of the explanation of the comprehensive legislation and administrative obligations, but also of sensitising and advising on technical issues. Technical issues were discussed mostly during individual guiding and in depth conversation with the farmer which was followed by a written report with findings and recommendations. Indeed, preventing nutrient losses, in particular losses of nitrates, demands the application on the farms of the so-called "4 R's principle". That means: the 4 appropriate things to think of when applying fertilisation: the use of the right type of fertiliser on the right time and right place and at the right rate. Important is the good understanding of the principles behind fertilisation, of nutrient cycles and of crop needs. Also important is the attention to the soil quality, as a pre-condition for well-growing and healthy crops with an effective root-system capable of taking up the nutrients present. Farm consultancy and sensitizing stopped at the end of 2017, together with a refocus on compliance enforcement considered as a public core mission. A major factor in that decision was the set-up in the meantime of the CVBB counselling service.

Coordination centre for education and guidance of sustainable fertilisation (CVBB)

CVBB or "coordination centre for education and guidance of sustainable fertilisation", has been active from 2012 onwards and through 2020. Set up as a non-profit structure by farmer federations and the Flemish provinces, the relevant Flemish public agencies only had a small consultative role. The coordination centre was funded also by the Ministry of Environment, through the VLM as the paying agency. CVBB adopted an independent attitude towards the public agencies, motivated as necessary to gain farmers' confidence, to attain open discussion and results on the field. New in the approach were the area-focused water quality groups with counsellors and farmers investigating the origin of poor water quality, all together with comprehensive water-sampling of numerous streams and streamlets. The water quality groups were focused on the so-called "red points". Red points are the measuring points of the public monitoring network of surface water (and the associated areas of land draining into the polluted waters) that do not meet the European quality requirement and that are hugely influenced by agricultural activities. An intensive approach was adopted towards farmers with nitrate sensitive corps in well-chosen red point areas, with sensitizing through soil sampling and N-advise and follow-up of the results, and that often on a pluri-year basis. Individual guidance was also part of the delivered services, first open to all farmers but lateron (as a consequence of the ending of the BAS-guidance) focused on farmers with poorer environmental results as detected by the VLM. A small fee had to be paid by the farmer for individual guidance. General communication was relatively poor, though in the last couple of years the appealing MAP-man campaign was launched informing the farmers on tricks and tips on fertilisation. That campaign has had the support from the farmer organisations' press-channels.

Counselling service towards a better soil and water quality (B3W)

Since 2021, counselling is done by the B3W service or "*counselling service towards a better soil and water quality*". Funded again by the Ministry of Environment, B3W came about through a public contract with the VLM as commissioning party. The contractor is a multidisciplinary team of 13 partners, i.e. technical and research centres for agriculture and with more weight of the research centres than before. An annual work-program with input from an external advisory committee made up by farmer organisations and relevant public agencies, determines the main content and activities to be developed. B3W sets an additional focus on the importance of soil.

Fig. 7.1:
B3W Meeting on a farm to discuss general issues, plans of action, machinery, grow of crops…

(Source: B3W / S. Janssens)

The goal of B3W is fostering the uptake of more sustainable practices and techniques on the individual farms. Central to this approach is the significant role of farmers. Through peer to peer learning, "ambassador farmers" inform their colleagues on the rightful implementation of a good technique or practice, ion its benefits and on tricks and tips. B3W should be seen as a hub for information exchange, where counsellors are technicians but also coaches towards more sustainability. Field activities are at the core of the B3W approach. Thematic exchange moments are directly focused on the exchange of thoughts and experiences, with for example themes as fertiliser fractionating, preventing soil erosion, improving soil structure, using the results of a soil scan, implementing crop fertilisation advice, … Focus-groups are small groups of farmers coming together and discussing how to improve environmental performance on their farms. Central in this are small-scale tests conducted on their own farm, to gain very practical experience on existing or more innovative techniques in order to detect bottlenecks, (extra) benefits, … About 6 meetings are foreseen in a timespan of 2 years. Examples of subjects covered in those groups are : cultivation of protein-rich crops, separation of liquid manure in a thick and a watery fraction, preventing and repairing soil compaction, fertilisation techniques in potatoes, leek, cauliflower, pear, … Individual guidance is part of the B3W services, but it is limited to farmers that are behind on the "right" techniques. Farmers eligible for individual guidance comes from a list drawn up by the VLM. Participation is voluntary, but important in that is the intrinsic motivation of the farmer. Also through individual guidance, more general insights can be gained on the average status of nutrient and soil management on the farms, although keeping in mind that the target group for individual guidance is farmers with poorer environmental results. Communication is the key factor in reaching a broad audience. General information, findings captured on the field, seasonal relevant information, … are disseminated through information-sheets, infographics, in depth articles, videos, short testimonials by farmers, posts on Facebook, the B3W website and the B3W newsletter, and also during agricultural fairs. Important is the format of the communication, and that to achieve effective information transfer. Last corner stone of the B3W is information preparation, in order to support the counsellors and farmers during field-activities, but also to feed communication. B3W is not a research centre, but aims at bringing information together and sharing knowledge. In case of need, knowledge gaps are pointed out and referred to the relevant bodies engaged in research. Much attention is paid to the validation of information and to the formulation of easy understandable and clear messages.

Fig. 7.2:
B3W meeting in the fields
(Source: B3W / S. Janssens)

The Nitrates Directive, Guiding farmers in Flanders: the overview, and lessons learned

The overview

“Farm consultancy and sensitizing” was the challenging establishment in 2007 of a new approach in which a public agency involves in a mix of administrative, legal and technical support of farmers as an additional way to reach the objectives of the Nitrates Directive. The “coordination centre for education and guidance on sustainable fertilisation” initiated an approach with broader involvement of farmers and local stakeholders. Also, the involvement of technical and research centres was clear, and has led to increased insights in the challenges induced by the Nitrates Directive. With the actual “counselling service towards a better soil and water quality” stronger emphasis is laid on the uptake of the appropriate practices and techniques, with a significant bottom up approach with responsibility from the farmer side. Communication using appropriate formats and channels was given the necessary place in the overall picture.

Fig. 7.3:
One of B3W’s communication formats: Farmer testimonial on his revised fertilizing practices in a handout

(Source: B3W / S. Janssens)

Water quality in Flanders does not meet the Directive’s required standards, and is still affected by agricultural activities. (Much) work remains to be done, and there is an (often underestimated) margin of improvement possible on the farms, justifying proper technical counselling and the stakeholders’ take of responsibility. That must necessarily be done inside the limits set by (a changing) regulatory environment with its comprehensive set of rules and obligations. Although not the only player in scenery of counselling, publicly subsidized counselling should set the tone. With the objective clearly in mind, questioning the working methods of guiding is of great importance, just as is expected from the farmers necessarily engaged in enhancing sustainability in food production.

Lessons learned

The sequence of approaches in counselling farmers in the context of the Nitrates Directive, was led by evolving insights gained from carrying out guidance. We want to share here some findings we experience to be key elements.

- have a fair approach about the current situation, expectations, and related challenges and be clear of the role and responsibility of all involved in the challenges to be taken up;
- prioritize the topics, and work on the right topics (big ones, ease wins, …); give a say about this to third parties and seek coalitions outside the advisory service;
- raise and increase the (basic) insights and make farmers understand… ; disseminate right, precise and useful practical information;
- deploy (broad) communication across different channels, have diverse and effective formats in communication and in (field) activities aiming at reaching the "fore-runners" and "those (far) behind";
- use the knowledge and the skills of farmers to convince other farmers, stimulate self-reflexion and -questioning of current practices and their consequences and effects;
- detect the reasons of resistance, and try to work resistance away;
- do have a diversity of skills inside the counselling service : technical, social and communicative skills; work closely together and align with each other;
- do think at the start about the (necessary) interaction and catalysing effects between information compiling, field activities and communication;
- question those you have counselled about what they think of it; also question yourself as counselling service and advisor.

(Authors of this contribution: Sébastien Janssens (Vlaamse Landmaatschappij), sebastien.janssens@vlm.be; Saartje Degelin (B3W), saartje.degelin@B3W.vlaanderen.be)

8. CONCLUSIONS AND RECOMMENDATIONS

1. Many groundwater bodies in the EU are not at good chemical status. The main pollutant leading to poor status is nitrate (9% of GWBs covering 18% of the GWB area), followed by pesticides, ammonium, chloride, sulphate, lead, nickel and arsenic. The main cause of this is agriculture with 20% of GWB area being affected by agricultural diffuse pollution (compared to 5% from sewage and 4% each from contaminated sites and industrial plants).

2. The EU environmental legislation, e.g. Water Framework, Groundwater and Nitrates Directives, has had a supplementary and progressive role in setting up a governance framework for safeguarding European groundwaters. However, implementation reports by the European Commission do not show any positive progress in groundwater bodies' overall status. Measures have been implemented widely across the EU and in participant countries, but they are often determined by budgets and policies in place. Long recovery time, restoration challenges and the fact that certain human pressures are difficult to mitigate without severe socio-economic consequences are other reasons why an overall positive trend is not yet noticeable.

3. Trend assessments by the EEA (for the EU as a whole) and in several participant countries of this project show that nitrate concentrations in groundwater have risen slowly over the past 20 years and still continue to rise. A trend reversal on a nationwide scale has so far been achieved only in Denmark.

4. Denmark has generally managed to reduce nitrate pollution of groundwater since the late 20th century. Overall there is a clear trend of a reversal at the beginning of the 1980s towards a more sustainable agricultural N management and a decline of N-surplus. Nitrogen field balance has been reduced by more than 40 % from 1990 – 2020 without a decrease in yields. There is also a clear trend towards a declining nitrate content in oxic groundwater based on the year of groundwater formation. In the last decade since 2012, at 31% of measuring points a decrease of nitrate was found, at 50% the situation was stable, and 18% showed an increase. After significant improvements in wastewater treatment (sewage was originally a major source of groundwater pollution), this reduction has been mainly achieved by a decrease in the use of inorganic fertilizers. In addition, the storage and application of manure have improved and the risk of accidents and leaks has been reduced. There is also an efficient control system to ensure compliance with the rules.

5. In other countries, a trend reversal in nitrate pollution has been observed locally, under certain specific conditions. Similar experiences have been made e.g. in Germany, England and Belgium. Some of the mitigation measures have not yet shown a positive effect due to long recovery times.

6. In the German state of Hessenn, cooperation agreements between water suppliers and farmers to reduce groundwater pollution in water protection areas have had some success, provided the agreements were implemented with intensive consultancy, good communication between all parties, compensation payments for economic losses and sanctions in the case of non-compliance.

7. In England, catchment schemes are used to protect vulnerable water resources, involving partnerships of water suppliers and landowners, advice by “catchment officers” and government funding on the one hand, but also financial penalties and/or prosecution for non-compliance with water law on the other. The Environment Agency has set nutrient emission limits for sectors (like agriculture) and for individual farms, leaving them scope to decide how to reach these limits. As a new idea to promote winter cover crops for reducing nitrate leaching, a “reverse auction” was used via the EnTrade environmental market platform to allocate water company funding, and efficiently scale the uptake of the measure.

8. In Flanders (the northern part of Belgium), there has been a succession of approaches of counselling farmers since 2007, as part of the flanking policy for achieving the goals of the EU Nitrates Directive. Initially the public agency in charge of the implementation of the Nitrates Directive (Vlaamse Landmaatschappij - VLM) was tasked to operate a “farm consultancy and sensitizing” service with a mixture of group guiding and individual guiding that was provided free of charge. This was stopped at the end of 2017, together with a refocus on compliance enforcement considered as a public core mission. Some years before, a counselling service carried out by the technical and research centres for agriculture had been set up as a non-profit structure by the flemish provinces and farmer federations with funding from the Flemish Ministry of the Environment. New in the approach were the “water quality groups” with counsellors and farmers investigating the origin of poor water quality and sensitizing farmers through intensive water- and soil sampling, focusing on “red point” areas where the Nitrates Directive water quality requirements were not met.

   Since 2021, counselling is done by the B3W service or “counselling service towards a better soil and water quality”, again with public money and based on a public contract with the VLM as commissioning party. B3W is a multidisciplinary team formed by 13 technical and research centres for agriculture, in which the research centres for agriculture have more weight than before. B3W sets an additional focus on the importance of soil as an underlying requirement for nutrient uptake and for environmental performance. An external advisory committee with the relevant public administrations and the farmers organisations contributes in the establishment of an annual work programme, allowing some flexibility in the field operations and thematic focuses.

Peer to peer learning between farmers is a keystone in the goal to apply sustainable practices and techniques on their farms ; B3W counsellors have an initiating and supporting role. A positive and fair approach, in which the challenges are clear as well as the possibilities in adopting the right techniques and practices, should stimulate self-questioning about existing practices among the farmers. By way of “thematic exchange moments”, an individual farmer acts as an ambassador for a proven good technique, and talks about tricks and tips. On a so-called "persuasion field”, a farmer applies under the guidance of B3W a good technique for the first time on his farm and tells his colleagues about the results and findings. “Focus-groups” bring some farmers together and allow them to do small-scale tests on their farms to gain experience on existing or more innovative techniques. Individual guidance is part of the B3W services, but limited to some farmers that are behind on the “right” technique. Information dissemination through diverse communication formats and media is a task of increasing importance within the B3W service. Info-graphics, short films, more in-depth booklets, press-articles, blogs about the “persuasion fields”, social media … should allow effective information transfer, promote the uptake of the right techniques and practices on the farms and enhance sustainability.

9. In the Italian region of Lombardy, mitigation measures have managed to reduce the use of pesticides since 2015 and thus the pollution of groundwater with substances like Bentazon, Metolachlor and Terbuthylazine. This was achieved by binding standards, public information and indirect controls via electronic registers relating to agropharmaceutical products and their use by farmers.

10. The Romanian experience is that the country fortunately lacks a long history of intensive agriculture, and thus nitrate pollution, and that policymakers are trying not to repeat the mistakes that were made elsewhere. Soil experiments play a role in helping to inform future agricultural policy.

11. In Malta there is still a negative trend of nitrate pollution, and in addition groundwater bodies are threatened by salinisation, as a consequence of seawater intrusion. A trend reversal could not be achieved in the last monitoring cycles.

12. Both recovery and restoration of groundwater bodies take a long time, as do changing practices that cause pressure on groundwater. So there is a need to continue following and fully implementing both EU and national environmental legislation.

13. Experience shows that measures must be implemented over the long-term (i.e. a minimum of several decades) without substantial changes. This gives landowners and operators certainty to make investment decisions on farming infrastructure and equipment.

14. There is a need to develop strong local relationships between advisors and farmers to build trust. This trust is important when implementing voluntary land use changes. In this context, it is important to find a balanced approach between successful groundwater protection and agricultural productivity.

15. It should be considered to run a demonstration farm scheme, so that other farmers can learn locally from best practice in reducing nitrate leaching and observe that groundwater protection measures do not necessarily lead to yield reductions.

16. All farm measures and schemes should be considered holistically so that advisors and regulators communicate a single agreed position with all farmers. This will help to avoid confusion and improve the efficiency of any scheme/measure as potentially there may be a number of on-farm initiatives happening at any one time e.g. EU farm to fork strategy, Common Agricultural Policy, the Organic Farming Plan, Welfare of Farmed Animals initiative etc.

Annex

ANNEX: BIBLIOGRAPHY AND USEFUL LINKS

(English language publications)

European Commission, Directorate-General for Environment: (Common Implementation Strategy) Guidance on groundwater status and trend assessment. Guidance document No 18, Publications Office, 2009, https://data.europa.eu/doi/10.2779/77587

European Commission, Directorate-General for Environment: (Common Implementation Strategy) Technical report nº 1. The EU Water Framework Directive: statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results, 2001, https://circabc.europa.eu/sd/a/a1f194ce-8684-436c-a130-ec88ee781bd2/Groundwater%20trend%20report.pdf

European Commission, Directorate-General for Environment: Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC) and the Floods Directive (2007/60/EC). Second River Basin Management Plans / First Flood Risk Management Plans, of 26.2.2019, COM(2019)95 final [=5th implementation report 2019], https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=COM:2019:95:FIN and also https://environment.ec.europa.eu/topics/water/water-framework-directive/implementation-reports_en

European Commission, Directorate-General for Environment: Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC), the Environmental Quality Standards Directive (2008/105/EC amended by Directive 2013/39/EU) and the Floods Directive (2007/60/EC). Implementation of planned Programmes of Measures New Priority Substances Preliminary Flood Risk Assessments and Areas of Potential Significant Flood Risk, of 15.12.2021, COM/2021/970 final [= 6th Implementation Report 2021], https://environment.ec.europa.eu/topics/water/water-framework-directive/implementation-reports_en

European Commission, Directorate-General for Environment: Proposal for a Directive amending the Water Framework Directive, the Groundwater Directive and the Environmental Quality Standards Directive, 2022, https://environment.ec.europa.eu/publications/proposal-amending-water-directives_en

European Commission, Joint Research Centre / Knowledge Hub for Water: Groundwater quality and vulnerability. Assessment tools to prevent and control groundwater pollution by nitrates, 2019, https://water.jrc.ec.europa.eu/khwa/knowledge/groundwater.html

European Environment Agency: European waters. Assessment of status and pressures 2018. EEA Report No 7/2018, https://www.eea.europa.eu/publications/state-of-water

European Environment Agency: Europe's groundwater – A key resource under pressure, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2800/50592

Foster, S. / Kaergaard Bjerre, T.: Diffuse agricultural pollution of groundwater: addressing impacts in Denmark and Eastern England, in: Water Quality Research Journal (2023) 58 (1): pp. 14–21, https://doi.org/10.2166/wqrj.2022.022

Frollini, E., et al.: Groundwater quality trend and trend reversal assessment in the European Water Framework Directive context: an example with nitrates in Italy, in: Environmental Science and Pollution Research (2021) 28:22092–22104, https://doi.org/10.1007/s11356-020-11998-0

Hansen, B., et al.: Trend Reversal of Nitrate in Danish Groundwater - a Reflection of Agricultural Practices and Nitrogen Surpluses since 1950, in: Environmental Science & Technology (2011), https://www.academia.edu/12996560/Trend_Reversal_of_Nitrate_in_Danish_Groundwater_a_Reflection_of_Agricultural_Practices_and_Nitrogen_Surpluses_since_1950

Hansen, B., et al.: Groundwater nitrate response to sustainable nitrogen management, in: Scientific Reports (Aug. 2017) 7: 8566 | DOI:10.1038/s41598-017-07147-2

Ortmeyer, F. / Hansen, B. / Banning, A.: Groundwater nitrate problem and countermeasures in strongly affected EU countries—a comparison between Germany, Denmark and Ireland, in: Grundwasser - Zeitschrift der Fachsektion Hydrogeologie 28, 3–22 (2023). https://doi.org/10.1007/s00767-022-00530-5

Umweltbundesamt: Waters in Germany. Status and assessment, 2017, https://www.umweltbundesamt.de/sites/default/files/medien/377/publikationen/171018_uba_gewasserdtl_engl_bf.pdf

Visser, A., et al.: Demonstrating trend reversal of groundwater quality in relation to time of recharge determined by 3H/3He, in: Environmental Pollution, Vol. 148, Issue 3, August 2007, pp. 797-807, https://doi.org/10.1016/j.envpol.2007.01.027