Review of measures to decrease nitrate pollution of drinking water sources

FAIRWAY Research Highlights

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In this report we **review and assess measures to decrease nitrate pollution of drinking water resources**. The work builds on insights and results gathered in EU-wide and global projects and studies. It provides an overview and assessment of the effectiveness and efficiency of measures aimed at decreasing nitrate pollution of drinking water reservoirs.

We review previously published reviews on measures aimed at decreasing nitrate leaching. Many of them are either focused on single measures or were rather qualitative and descriptive in nature. The novel aspect of this review is that the accessible literature has been screened for experimental data related to the effectiveness of most measures to reduce nitrate pollution of groundwater and surface waters, in a coherent and quantitative manner, using statistical analyses.

We conducted two surveys:

- Firstly, a survey of practical guidelines and measures, also at the case study sites, and earlier inventory reports yield gross lists of some 40 measures. All these measures were uniformly and concisely described.
- Secondly, a survey of published literature was conducted to identify papers that reported experimental results on the effectiveness of measures to decrease nitrate leaching, using the ISI-Web of Science and Google Scholar from 1980 to 2017. The reviews were conducted by different review teams covering different geographical regions using an approved protocol. Results were stored in a database and analyzed statistically.

Background information is provided about the sources of nitrate nitrogen in agriculture and about the processes and factors that contribute to the pollution of groundwater and surface waters with nitrates. The nitrogen cycle has been characterized as leaky and complex. Main sources are animal manures and synthetic fertilizers, but also residues and wastes, and the mineralization of soil organic matter following land use change can be sources regionally. Estimates suggest that some 60% of the amounts of nitrogen entering the aquatic system originates from diffuse agricultural sources in EU-28, which is about 6 Tg (1 Tg is 1 million ton is 1012 g), and equivalent to 60% of the N fertilizer use in EU-28.

Background information is also provided about agricultural systems and land use in EU-28 and about management factors that influence nitrogen use in agriculture. The nitrogen input-output balance is a synthetic manner for summarizing N use at farm level but also at regional and national levels. We also

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discuss the difficulties of optimizing N fertilization due to site and temporal variations in N demands by growing crops.

The hydrological cycle and pathways of N transfers from land to groundwater and surface waters are described. The potential risks of runoff and leaching of nitrate and nitrogen to surface waters is determined by a combination of pedo-climatic factors and the amounts of nitrate and nitrogen in the topsoil. Important pedo-climatic factors are:

i. rainfall amount and distribution, especially heavy rainfall events, and
ii. water infiltration rate into the soil.

The latter is determined by slope, soil texture, soil structure, soil depth to underlying rock, vegetation cover, snow and frost and freeze-thaw cycles, and the presence of terraces, tree lines, buffer zones, riparian zones, which all contribute to intercepting overland flows. Soils with a high nitrate leaching vulnerability have a high infiltration rate and a high hydrological conductivity, such as coarse-sandy soils and shallow soils overlying karst formations.

The mean cost-effectiveness of most measures aimed at decreasing nitrate losses from agriculture to ground and surface waters roughly ranged from 1 to 5 euro per kg N, but the uncertainty in the cost-effectiveness is large, and some measure had higher costs. At farm level, the cost of the measures ranged from a net gain to a cost of more than a few thousand euro per year.

Further detail is given about the rational and effectiveness of 11 key measures and serves as basis for a further quantitative analysis.

A total of 84 papers with 228 experimental comparisons are examined and utilized for statistical analyses; these papers report experimental data related to measures aimed at decreasing nitrate leaching losses. Most measures were on effective overall, but some not as effective as others. Effective measures were

i. N input control,
ii. adjustment of crop type and/or crop rotation,
iii. growth of cover crops,
iv. minimum tillage and surface mulching, and
v. nitrification inhibitors.

Somewhat surprisingly, fertilizer type and time and method of application turned out to be not effective. These initial results need further underpinning. Moreover, the effective measures do show a wide variation; the 95% confidence interval of the mean response ratio was often very large, which is probably related to site-specific variations in socio-economic and environmental conditions.

The importance decreasing nitrate pollution and considers the effectiveness, cost-effectiveness and applicability and adoptability of different measures. Our findings largely confirm the observations of earlier reports, but some meta-analysis studies provide additional and different results.

In summary, the variability in the effectiveness of measures to decrease nitrate leaching losses across sites is possibly one of the reasons for the widespread recording of nitrate concentrations exceeding 50 mg/L in groundwater and surface water monitoring stations, despite the implementation of series of measures during the last 2 to 3 decades. It shows a need for farm-specific packages of measures. This review is an important scientific building blocks for the further development of innovative measures and governance approaches for a more effective drinking water protection, together with local, regional and national actors.