Nitrate Problems are Soluble – but Who Pays?

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Nitrate pollution in rivers, lakes, reservoirs and underground aquifers is a major problem. However, researchers from Belgium, Malta, Poland, and the UK have developed a new low cost, environmentally friendly technology, known as 'NITRABAR' which substantially removes nitrate from groundwater. The project is an EC LIFE Environment Project that demonstrates the remediation of agricultural diffuse NITRAte polluted waters through the implementation of a permeable reactive BARrier.

Now that the science has been proven and the environmental and financial benefits have been calculated, the only outstanding issue is funding.

NITRABAR
A pan-European EC Life Environment Project

The Problem

Chemical fertilisers and manure can substantially improve the yields of agricultural crops and the profitability of production systems. However, nitrate is highly soluble and easily pass into soil, groundwater and surface water. As a result, levels of nitrate in many groundwater bodies and rivers throughout Europe have increased over the last 50 years. This affects the ecological quality of freshwater and coastal habitats which has knock-on effects on the recreational value and rural economy of the affected areas. It has been estimated by the European Environment Agency that agriculture is responsible for 50-80% of the total nitrate load in European waters.

Atmospheric deposition, discharge from septic tanks and leaking sewers, the spreading of sewage sludge to land and seepage from landfills can also contribute to the pollutant load (Bishop, Misstear, White, Harding. 2007)

Chemical fertilisers have been responsible for large increases in agricultural production over recent decades and it will not be a realistic possibility to incur substantial reduction in their use, particularly in the light of the comments made earlier this year by the head of the UN's Food and Agriculture Organisation, Dr Jacques Diouf, who said that global food production must double by 2050 if the world is to avoid mass hunger.

The European Community has been taking steps to reduce nitrogen pollution in waters for over twenty years. Whilst the initial directives were mainly concerned with water for human consumption, more recent directives, such as those covering nitrates from agricultural sources and urban waste water treatment, have placed increased emphasis on the environmental effects of excess nitrogen, such as eutrophication.

Eutrophication in surface water bodies results from excessive plant (usually algal) growth, low oxygen levels and lower biodiversity. Algal blooms have become an unfortunate feature of many water systems. In extreme cases, oxygen depletion results in the death of invertebrates and fish.

Nitrate is not directly toxic to humans, but in highly reducing conditions (oxygen-free) such as in the human gut it converts to nitrite, which can be toxic. For this reason, European drinking water standards have been set to safeguard against this, but at considerable cost of treatment to the consumer. Typically nitrate polluted water is treated by an ion exchange process. For example, Yorkshire Water (UK) recently placed an order for a nitrate removal plant at a cost of £4m (€4.7m).

The Costs

Nitrate reduction costs, through changes in land management, manure storage and fertiliser application, lie in the range of €50-150 per hectare per year, but this is estimated to be 5 to 10 times cheaper than removing nitrate from polluted water (European Commission, 2002). In the UK alone, the cost to the water industry to reduce high nitrate levels caused by diffuse pollution in drinking water supplies has been estimated at €310 million (capital expenditure) and €6.5 million per annum (operating expenditure) for the 2005-2010 period.

These costs are not static and are set to rise as groundwater concentrations continue to increase (Defra, 2007).

When the results for NITRABAR are compared with other methods, it is clear that the range of cost-effectiveness of NITRABAR (22 to 80 Euros per kg) overlaps the range of other agricultural methods. It should be noted that although NITRABAR is toward the upper range of values, it would become more cost-effective in longer installations than 100m due to economies of scale.

Commenting on the cost/benefit analysis, Prof Robert Kalin from the University of Strathclyde says, "The demonstration site was constructed to deal with much higher (experimentally dosed) levels of nitrate pollution than would normally be encountered and the cost analysis included many costs, such as monitoring, that will not be necessary for practical applications. So, future NITRABAR installations can expect to incur far lower costs. For example, we believe that a low cost trenching tool will be sufficient for many installations."

Legislation

Three key regulatory instruments impact upon initiatives to reduce nitrate levels in water bodies in Europe - Nitrates Directive, Water Framework Directive and Common Agricultural Policy.

The Nitrates Directive, adopted by the European Union in 1991, aims to reduce water pollution caused by nitrogen from agricultural sources and to prevent such pollution in the future. It requires Member States to designate Nitrate Vulnerable Zones and to establish a voluntary code of good agricultural practice to be followed by all farmers throughout the country.

Importantly, Member States are also required to establish a mandatory Action Programme of measures for the purposes of tackling nitrate loss from agriculture.

The Water Framework Directive is designed to improve and integrate the way water bodies are managed throughout Europe. It states that Member States must aim to reach good chemical and ecological status in inland and coastal waters by 2015.

The European Union's Common Agricultural Policy provides financial support to farmers for a range of farming, environmental and rural development activities as well as controlling EU agricultural markets.

The Solution

A number of options can be considered for reducing nitrate loadings to water. These range from agricultural management changes to high technology treatment processes. The methods can be generally grouped into the following categories:

- Land use change
- Soil management
- Livestock management
- Fertiliser management
- Manure management
- Farm infrastructure
- Water treatment
- Groundwater interception

The first six options will have to be considered as part of good agricultural practise, but farmers need to maximise profitability per hectare, so it is inevitable that nitrate pollution will be produced.

Water treatment has been considered to be a last resort due to its high cost and the benefits of managing pollution as close as possible to the source.

The potential for interception of groundwater on farms has not been explored, with the exception of a small number of research and development projects (e.g. Schipper and Vojvodić-Vuković, 2001) that have established the potential viability of permeable reactive barrier technology to treat nitrate in groundwater.

The NITRABAR system, designed by Prof. Kalin, consists of a trench containing a mixture of natural materials, a permeable reactive barrier, which removes nitrate from shallow groundwater immediately before it enters rivers or lakes.

A key feature of the NITRABAR system is its ability to convert dissolved Nitrates in the groundwater to harmless Nitrogen gas through the action of bacteria. This process is known as denitrification and involves a transition from nitrate (NO_3) to nitrite (NO_2) to nitric oxide gas (NO) to nitrous oxide gas (N_2O) and ultimately to nitrogen gas (N_2).

The denitrification process requires a source of carbon, which is why it does not take place naturally within an aquifer. Organic materials such as straw or trimmings from vegetation clearance can be employed as the source of carbon within the NITRABAR trench.

The NITRABAR project has been underway since December 2005 and in order to test the technology a demonstration site has been established at the Ecos Millennium Environmental Centre, Ballymena in Northern Ireland where the NITRABAR system is being continuously monitored to prove its performance under varying ground conditions and nitrate fluxes.

The NITRABAR demonstration site lies alongside the Braid River, which rises in the Antrim hills and is a tributary of the River Main, which ultimately flows in to Lough Neagh. The Braid River catchment includes a variety of types of farming activity. The permeable reactive barrier at the demonstration site has been installed 1.5 to 3.2 m below the ground. It is 80m long, 1.7m deep and 1.8m thick.

Trial Results

A team of experts at University of Strathclyde, led by Professor Kalin, has been collecting monitoring data at the Ballymena site since early 2008 and results indicate that nitrate is being effectively removed within the barrier, with concentrations at the inlet being reduced by over 90% as water moves through the barrier. Evidence that denitrification is occurring and that nitrate is not being lost to the environment has been gathered and monitoring data are available on the NITRABAR website (www.nitrabar.eu).

Water samples were collected to underpin the technical demonstration, at frequent intervals for laboratory analysis and gas analysis has been undertaken onsite with a portable FTIR multiparameter gas analyser.

Commenting on the results achieved to date, Project Manager Dr. Bruce Howard says, "The idea behind NITRABAR is simple: harnessing a natural process to deal with diffuse nitrate pollution - one of modern agriculture's most intractable environmental legacies. The challenge now is to encourage farmers, government agencies, environmentalists and others to work together to replicate the approach across Europe at the local level."

Farmer Response

NITRABAR has toured various farm shows in Poland, Ireland and the UK and the agricultural community has reacted very positively to the concept – particularly the idea that waste materials from the farm such as straw, trimmings from vegetation clearance etc, could be put to good use.

However, there is nothing at present which would force a farmer to invest in NITRABAR. A limitation of the Nitrates Directive (which does force farmers to implement so-called Best Management Practices for the reduction of nutrient loss) is that it only provides for the reduction of ongoing inputs rather than for dealing with the legacy of nitrate contamination in groundwater.

Conclusions

Stakeholders in nitrate reduction initiatives include: farmers needing to maintain or improve agricultural production whilst complying with increasingly stringent environmental regulations; the Environment Agency needing to find new ways to respond to the legislation by reducing nitrate pollution; water companies having to treat polluted raw water and consumers having to fund water company capital and operational budgets.

NITRABAR is able to remove over 90% of the Nitrate load in surface water and is the only technology that tackles the legacy of Nitrate contamination in shallow groundwater.

Clearly, as a cost-effective treatment for both existing and future Nitrate pollution, the case for widespread adoption of NITRABAR is compelling, so the only remaining issue is to establish a financial structure that will encourage rapid uptake of the technology.

The Future?

The partners in the NITRABAR Project hope that, having demonstrated the technology in a robust manner, replication will be facilitated by grant schemes similar to that which has encouraged riparian buffer strips.

The great advantage of NITRABAR is that it is low cost (using waste materials) and effectively has zero land take (it can be buried below ground).

It may also be possible that restrictions on fertiliser usage could be less severe if a farmer can demonstrate that he/she is reducing nutrient losses to water courses by means of technologies such as NITRABAR.

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