Chapter 9

Water quality: Nitrates, phosphorus and pesticides

This chapter reviews the environmental performances of agriculture in OECD countries related to water quality. It provides a description of the policy context (issues and main challenges), definitions for the agri-environmental indicators presented, and elements related to concepts, interpretations, links to other indicators, as well as measurability and data quality. The chapter then describes the main trends of the agri-environmental indicators, using available data covering the period 1990-2010 and based on a set of tables and figures.

9.1. Policy context

The issue

Improving water quality is consistently ranked as a top environmental concern in public opinion surveys across most OECD countries. Over decades, policy actions and major investment in OECD countries has helped to drastically reduce water pollution from urban centres, industry and sewage treatment works, with substantial gains for the economy, human health, environment and social values linked to water. In the light of this success focus has now switched in many countries to addressing agricultural water pollution. This is because agricultural water pollution principally originates from farms spread across the landscape (diffuse source pollution), as opposed to more spatially confined sources, such as urban centres and sewage treatment works (point source pollution). But agriculture is also a point source of water pollution, for example, from intensive livestock farms and the disposal of residual pesticides (OECD, 2012).

Policy responses to address agricultural water pollution across OECD countries have typically used a mix of economic incentives, environmental regulations and information instruments. A large range of measures have been deployed at the local, catchment, through to national and transborder scales, across an array of different government agencies. Many approaches to control water pollution from agriculture are voluntary, for example, water supply utilities and the agro-food chain are engaged in co-operative arrangements with farmers to minimise pollution, such as providing farm advisory services. These policies and approaches have had mixed results in lowering agricultural pressure on water systems (OECD, 2012).

Main challenges

The key challenges for policy makers in addressing water quality issues in agriculture are to reduce farm contaminant lost into water systems (negative externalities) while encouraging agriculture to generate or conserve a range of benefits associated with water systems (positive externalities). Clean water is vital in securing economic benefits for agriculture and other sectors, meeting human health needs, maintaining viable ecosystems, and providing societal benefits, such as the recreational, visual amenity, and cultural values society attaches to water systems (OECD, 2012).

9.2. Indicators

Definitions

The indicators related to agricultural water quality include changes in:

- Nitrate, phosphate and pesticide pollution derived from agriculture in surface water, groundwater and marine waters.

Concepts, interpretation, limitations and links to other indicators

Agricultural pollution of water bodies (rivers, lakes, reservoirs, groundwater and marine waters) relates to firstly, the pollution of drinking water, and secondly, the harmful effects on aquatic ecosystems. The latter may result in damage to aquatic organisms, and costs for recreational activities (e.g. swimming), commercial fisheries in both fresh and marine waters, other commercial users (including agriculture) of water drawn downstream, and other values society attaches to water (e.g. visual amenity).

The limitations to identifying trends in water pollution originating from agriculture are in attributing the share of agriculture in total contamination and identifying areas vulnerable to agricultural water pollution. In addition, differences in methods of data collection and national drinking and environmental water standards hinder comparative assessments, while monitoring agricultural water pollution is poorly developed, especially for pesticides, in a number of countries.

The extent of agricultural groundwater pollution is generally less well documented than is the case for surface water, largely due to the costs involved in sampling groundwater, and because most pollutants take a longer time to leach through soils into aquifers. Moreover, the extent of monitoring in agricultural areas in terms of detecting pollution above recommended environmental and recreational use limits is less developed compared to monitoring of drinking water.

A further limitation to the water quality indicators included in this chapter, relate to differences in the monitoring systems used to track nutrient and pesticide pollution of water across countries. These differences include, for example, the number of monitoring stations, the location of monitoring sites in predominantly agricultural water catchments, and the frequency with which readings are taken at a monitoring site, both within a day and at which times during the entire growing season. Hence, comparisons between countries need to be treated cautiously.

The scale of the impairment of water systems due to agriculture described in this chapter also needs to be placed in some perspective. Across most regions in OECD countries drinking water quality is high and there are limited health risks linked to impaired drinking water, although water treatment costs can be significant to remove pollutants (OECD, 2012). Agriculture is also not the only source of contamination of water systems.

Changes in nutrient balances (Chapter 4), pesticide sales (Chapter 5) and soil erosion (Chapter 7) are the key driving forces that are linked to water quality indicators which describe the state of water quality in agricultural areas and define the contribution of nutrient and pesticide pollution originating from agricultural activities (assessment of soil sediment damage from agriculture into water systems is not examined in this report). Adaptation of a range of farm management practices are the response by farmers to reduce pollutant run-off from farmland into water bodies.

Measurability and data quality

Most OECD countries have monitoring networks to measure the overall quality of water systems. However, monitoring of agricultural pollution of water bodies is more limited, with around a half of OECD member countries regularly monitoring nutrient and pesticide pollution (see the figures in this chapter and Annex 1.A2). There are three main sources of information in this chapter, including: the OECD (2008) survey of the overall impacts of agriculture on water systems over the period from 1990 to the mid-2000s across

OECD countries; a more recent OECD (2012) review of national surveys of water quality trends related to agriculture from the mid-2000s to 2010; and updated data provided by OECD countries for this report.

Certain farm pollutants are recorded in more detail and with greater frequency (e.g. nutrients, pesticides), whereas an indication of the overall OECD situation for water pollution from soil sediments, pathogens, salts and other agricultural pollutants is unclear (OECD, 2012). Moreover, pollution levels can vary greatly between OECD countries and regions within countries, depending mainly on soil and crop types, agro-ecological conditions, climate, farm management practices, and policies (Figure 1.1; OECD, 2012).

9.3. Main trends

General overview

The overall trends of agricultural water pollution from nitrates, phosphorus and pesticides across OECD countries are mixed over the period 2000 to 2010, but there appear few situations where significant improvements are reported. Recent national assessments of water pollution related to agriculture, together with limited data on national trends in agricultural water pollution, show a variable picture between countries in terms of the: trends of agricultural water pollution by contaminant type; contribution of agriculture in total pollution; and the extent to which contaminants exceed drinking water standards (OECD, 2012).

For the 15-20 OECD countries that track nutrient and pesticide concentrations in surface water and groundwater, about half record that 10% or more monitoring sites in agricultural areas have concentrations that exceed national drinking water limits (see below Figures 9.5, 9.7 and 9.9). But monitoring sites measuring concentrations in excess of drinking water standards varies greatly between countries, contaminants, and surface and groundwater. For example, the share of monitored sites where pesticide concentrations are above drinking water standards for surface and groundwater supplies are generally lower than for nutrients. But concerns remain for pesticide pollution of groundwater (see below Figures 9.8 and 9.9).

The water consumed by most of the population across OECD countries, however, is well within drinking water standards due to effective treatment to remove these pollutants, which is estimated to cost water treatment companies and consumers billions of dollars annually. But in some rural areas of OECD countries, which are not connected to treated water infrastructure systems, health concerns can be more significant from agricultural water pollution, especially where water is drawn from shallow wells.

The downward trend in nutrient surpluses and pesticide sales over the past 10 years for many OECD countries, however, would suggest that pressure from agriculture on water systems has eased (Chapters 4 and 5). Moreover, overall improvements in slowing rates of soil erosion on agricultural land across many OECD countries, would also indicate that the risk of agricultural water pollution could be declining, as soil sediment is a major pollutant of water systems, including the transportation by soil particles of pollutants into water (Chapter 7; OECD, 2012).

The apparent dichotomy between decreasing agricultural pollutant loads but stable or deteriorating readings of water pollution at monitoring sites, is to a large extent explained by time lags (OECD, 2012). A time lag (sometimes referred to as the legacy problem) is the time elapsed between the adoption of management changes by farmers and the detection of measurable improvement in water quality of the target water body (Fenton et al., 2010; Kronvang, Rubaek and Heckrath, 2009; Meals, Dressing and Davenport, 2010; Schulte et al., 2010).

The magnitude of the time lag is highly site and contaminant specific and can take: hours to months for some contaminants after heavy rainfall, especially point sources in agriculture; years to decades for excessive phosphate levels in agricultural soils; and decades or more for sediment accumulated in river systems (Meals, Dressing and Davenport, 2010). Nutrient enriched lakes and acidified waters may also take years to recover (Environment Agency, 2007). Groundwater travel time is also an important contributor to time lags and may introduce a lag of decades between changes in agricultural practices and improvements in groundwater quality (Collins and McGonigle, 2008; Dubrovsky et al., 2010; Environment Agency, 2007; Meals, Dressing and Davenport, 2010).

Overview for the European Union and other selected OECD countries

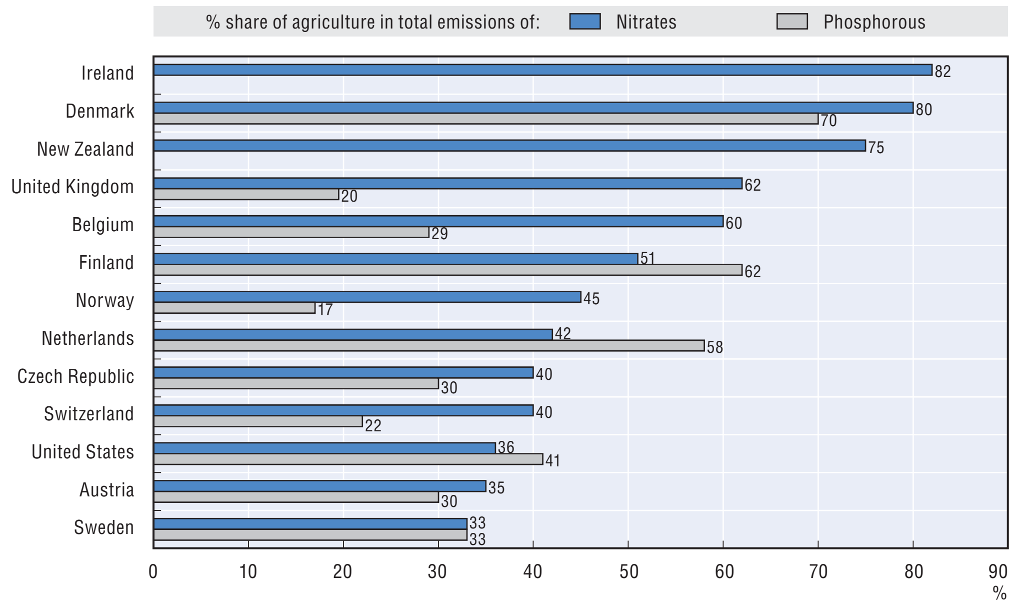
Across most **European Union** member states agriculture is an important source of nutrients and pesticides into surface and groundwater (European Environment Agency, 2010). While there are differences in trends and absolute pressures from agricultural nutrient surpluses on water systems across member states, the contribution of agriculture remains high. More specifically in most member states agriculture is responsible for over a third of the total nutrient discharge to surface and coastal waters (Figures 9.1 and 9.3), although the overall trend in agricultural nutrient discharges has been declining since the mid-1990s for some but not all countries (see Figures 9.2, 9.4 and 9.7; and European Environment Agency, 2010; European Commission, 2010). Even so, around a third of EU15 surface water and groundwater monitoring stations still show an upward trend in nitrate concentration levels in water and eutrophication of fresh and marine waters is significant (European Commission, 2010).

Although varying regionally in nature and severity, agricultural influences on water quality are important, according to the **United States** Geological Survey *National Water Quality Assessment Program* (USGS, 2010). Nationally, agriculture is estimated to account for around 60% of river pollution, 30% of lake pollution and 15% of estuarine and coastal pollution. Agriculture also contributes significantly to groundwater contamination (wells and aquifers) across the nation, especially from leaching of nutrients and pesticides (see below Figures 9.6 and 9.8; and USGS, 2010). Of growing concern for groundwater quality is the increasing and widespread detection of contaminant mixtures, including mixtures of pesticides and veterinary products from agriculture with other man-made and natural contaminants (USGS, 2010).

Risks to water quality associated with agriculture currently has a good status in **Canada** (Figure 9.5), but represents an overall decline from a desired state in 1981. Increased application of nutrients (N and P), as fertiliser and manure, has been the main driver for the declining trend in the performance index for agricultural water quality throughout Canada (Eilers et al., 2010). Increased efforts are required across Canada to minimise the risk of nutrient, pesticide and coliform movement to surface water bodies and leaching beyond the rooting depth of vegetation. This is particularly so in higher rainfall areas of the country (Eilers et al., 2010).

Whilst over 90% of rivers meet health related water quality standards in **Japan**, many lakes, reservoirs and coastal waters do not (OECD, 2010). Nitrates, pesticides and sediments from agricultural activities are acknowledged to be among the causes of these problems, as

Figure 9.1. **Agriculture emissions of nitrates and phosphorus in surface water, OECD countries, 2000-09**



Notes: Countries are ranked in descending order of highest share of nitrates in surface water.
For nitrates, the figures presented correspond to the year 2000 for Austria, Czech Republic, New Zealand, Norway, Switzerland and United States; 2002 for Denmark; 2004 for Finland and Ireland; 2005 for Belgium (Wallonia); 2008 for United Kingdom; and 2009 for Netherlands and Sweden.
For phosphorous, the figures presented correspond to the year 2000 for Austria, Czech Republic, Norway, Switzerland and United States; 2002 for Denmark; 2004 for Finland; 2005 for Belgium (Wallonia); and 2009 for Netherlands, Sweden and United Kingdom.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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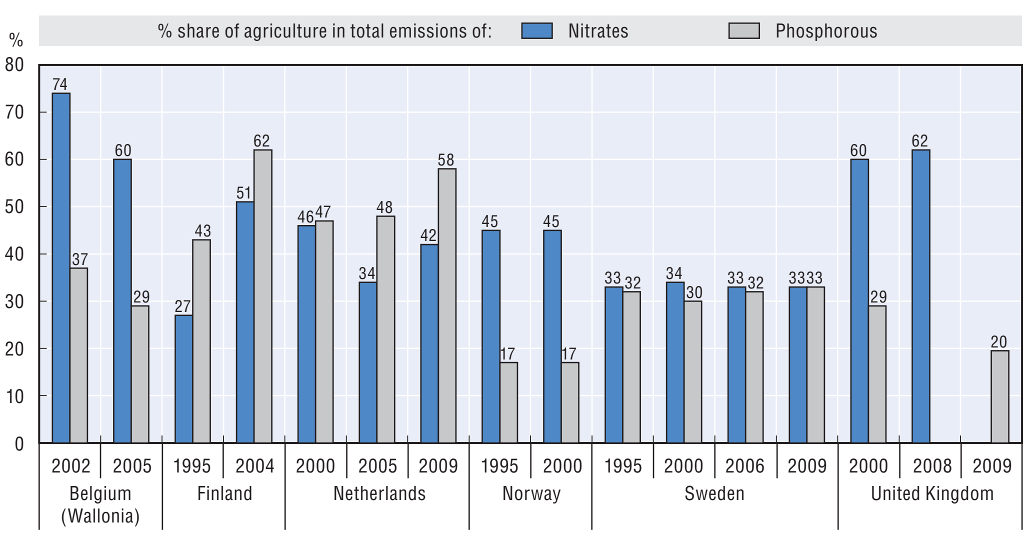
Figure 9.2. **Trends in agriculture's emissions of nitrates and phosphorus in surface water, OECD countries, 1995-2009**



Note: Countries are in alphabetical order.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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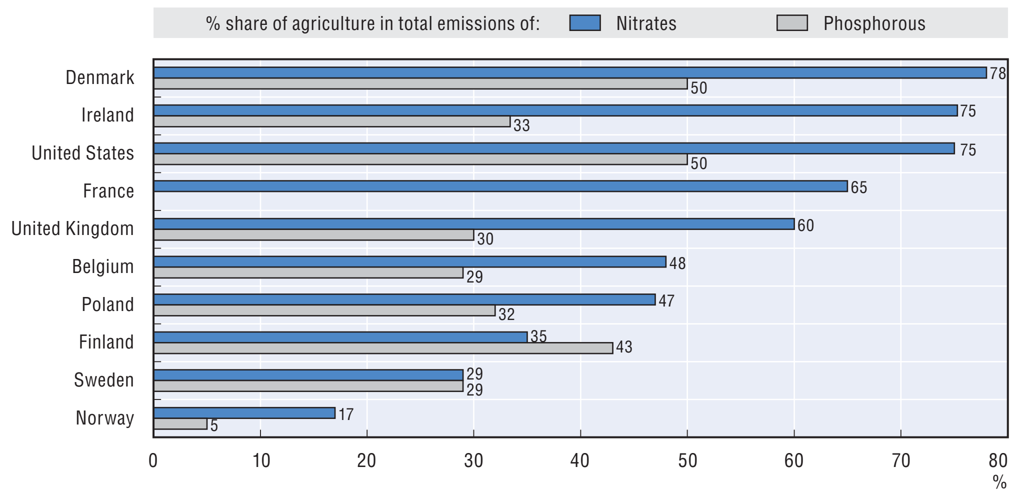
Figure 9.3. **Agriculture emissions of nitrates and phosphorus in coastal water, OECD countries, 2000-09**



Notes: Countries are ranked in descending order of highest share of nitrates in coastal waters.
For nitrates, the figures presented correspond to the year 2000 for France, Poland, United Kingdom and United States; the year 2002 for Denmark; the year 2003 for Belgium (Flanders); the year 2005 for Ireland; the year 2006 for Finland; and the year 2009 for Norway and Sweden.
For phosphorous, the figures presented correspond to the year 2000 for Poland, United Kingdom and United States; the year 2002 for Denmark; the year 2003 for Belgium (Flanders); the year 2005 for Ireland; the year 2006 for Finland; and the year 2009 for Norway and Sweden.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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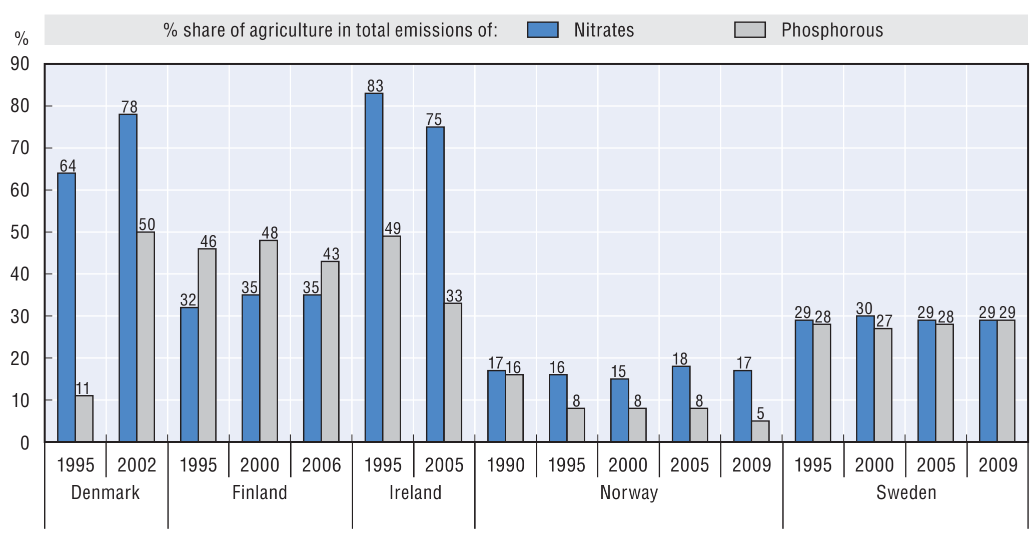
Figure 9.4. **Trends in agriculture's emissions of nitrates and phosphorus in coastal waters, OECD countries, 1995-2009**



Note: Countries are in alphabetical order.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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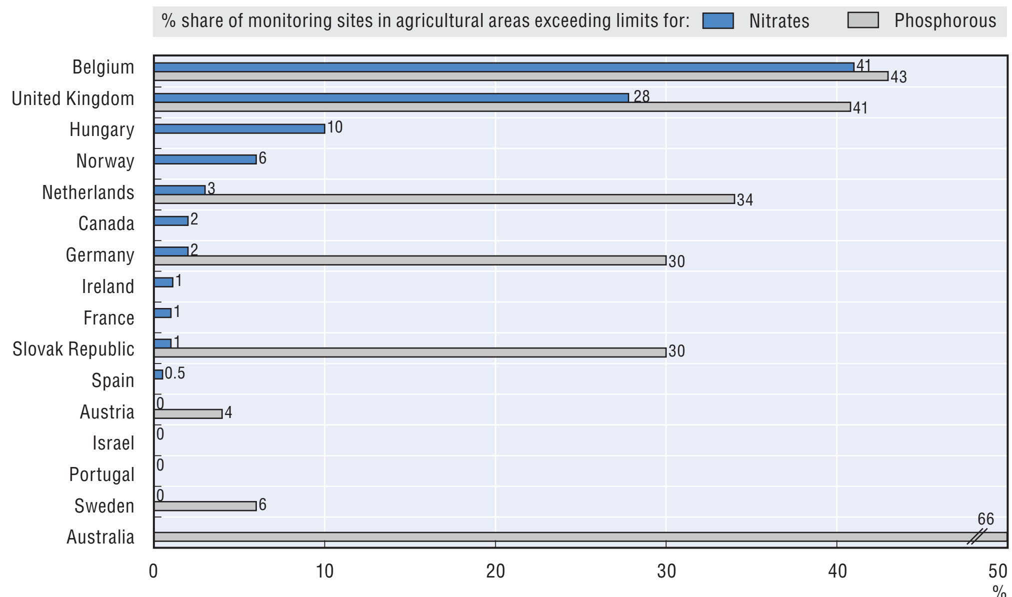
well as discharges from other sources (e.g. sewage, industrial). Eutrophication continues to be a concern from nutrients, including from agriculture, especially intensive livestock operations but also fertiliser use, leading to frequent algae blooms (red and blue tides) that damage aquatic life in coastal areas and increase costs of water treatment from inland water intakes (Ileva et al., 2009). The quality of groundwater is improving, with nitrogen

Figure 9.5. **Agricultural areas that exceed recommended drinking water limits for nitrates and phosphorous in surface water, OECD countries, 2000-10**



Notes: Countries are ranked in descending order of highest share of monitoring sites exceeding nitrate drinking water limits. For nitrates, data are not available for Australia. For phosphorous, data are not available for Canada, France, Hungary, Ireland, Israel, Norway, Portugal and Spain.
For nitrates, the figures refer to the year 2000 for Austria, Germany, Hungary, Norway and Sweden; the year 2001 for Belgium (Flanders) and Spain; the year 2002 for Slovak Republic; the year 2005 for Portugal; the year 2008 for France; the year 2009 for Canada, Ireland and United Kingdom; and the year 2010 for Israel and Netherlands. Value is zero or less than 0.5% for nitrates for Austria, Israel, Portugal and Sweden.
For phosphorous, the figures refer to the year 2000 for Germany and Sweden; the year 2001 for Austria and Belgium (Flanders); the year 2002 for Australia and Slovak Republic; the year 2009 for United Kingdom; and the year 2010 for Netherlands.
The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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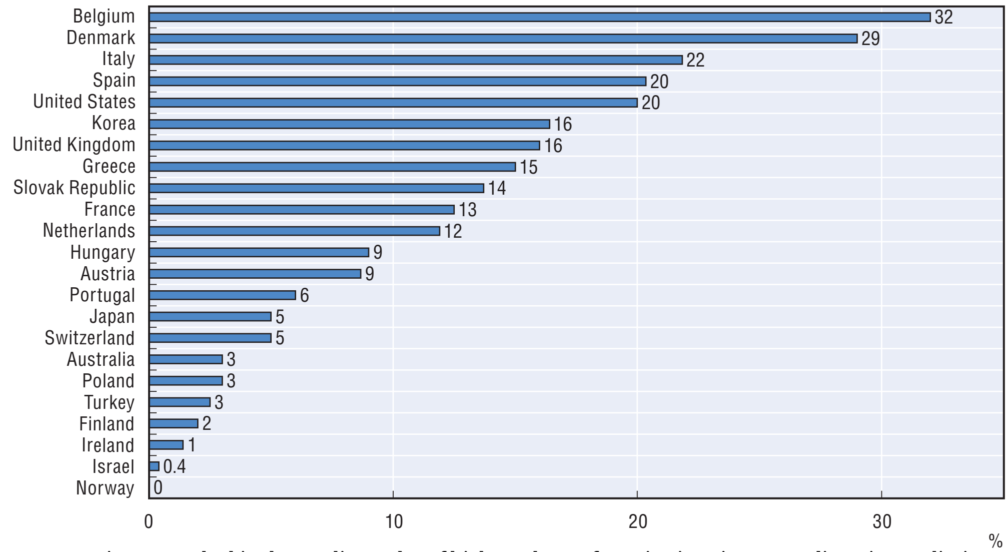
(from all sources including agriculture) exceeded in 5% of monitored wells (Figure 9.6) and less than 0.1% of surface water for pesticides (Figure 9.9). The potential of paddy fields to mimic natural wetlands and filter excess nutrients can provide some benefits for water quality under certain management practices (OECD, 2012).

Despite some recent improvements in **Korea**, around a third of rivers fail to meet domestic quality standards and over a quarter of lakes are eutrophic (OECD, 2012) and 16% of monitoring sites for nitrates in groundwater exceeded recommended drinking water limits in 2000 (Figure 9.6). Coastal eutrophication is a localised problem for fisheries and aquaculture. Diffuse pollution, including from agriculture, is acknowledged as a source of pollution with increases in livestock numbers a growing pressure on water systems (Figure 3.3). Paddy fields mimicking natural wetlands hold the potential to improve water quality.

Problems in **Australia** arising from agricultural contaminants and salinity have been exacerbated by low flow conditions caused by abstraction and less than average rainfall in recent years (OECD, 2012). Most rivers exhibit a high degree of degradation, particularly within the Murray-Darling catchment, Australia's main agricultural producing region. Drinking water quality is impaired in many locations, and coastal regions downstream of large agricultural

Figure 9.6. **Agricultural areas that exceed recommended drinking water limits for nitrates in groundwater, OECD countries, 2000-10**



Notes: Countries are ranked in descending order of highest share of monitoring sites exceeding nitrates limits.
The figures refer to 2000 for Japan, Korea, Turkey and United States; 2001 for Greece; 2002 for Australia, Finland, Hungary and Norway; 2003 for Denmark, Italy and Spain; 2005 for Belgium (Flanders), Portugal and Slovak Republic; 2008 for France and Poland; 2009 for Switzerland; and 2010 for Austria, Ireland, Israel, Korea, Netherlands and United Kingdom.
The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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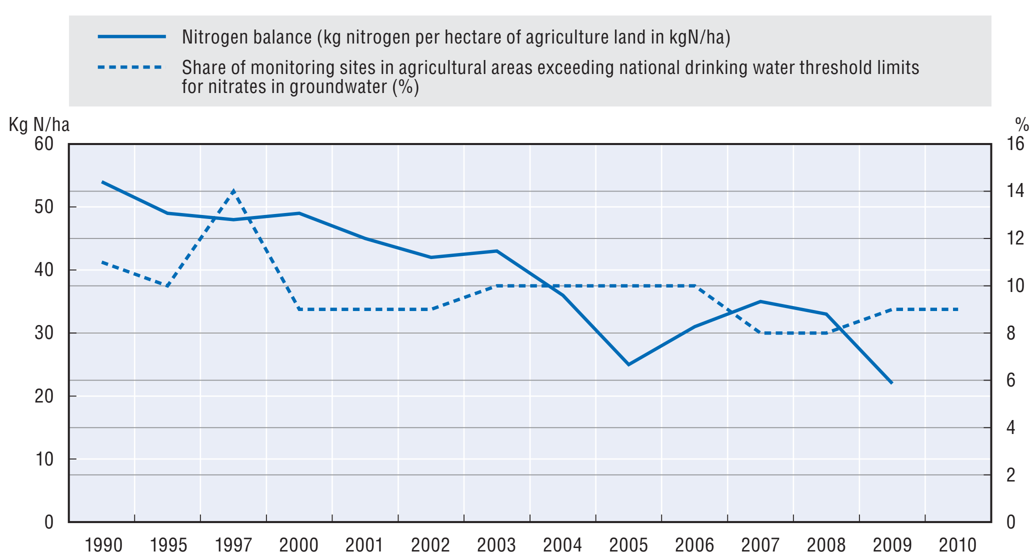
Figure 9.7. **Agricultural areas exceeding national drinking water limits for nitrates in groundwater, Austria, 1990-2010**



Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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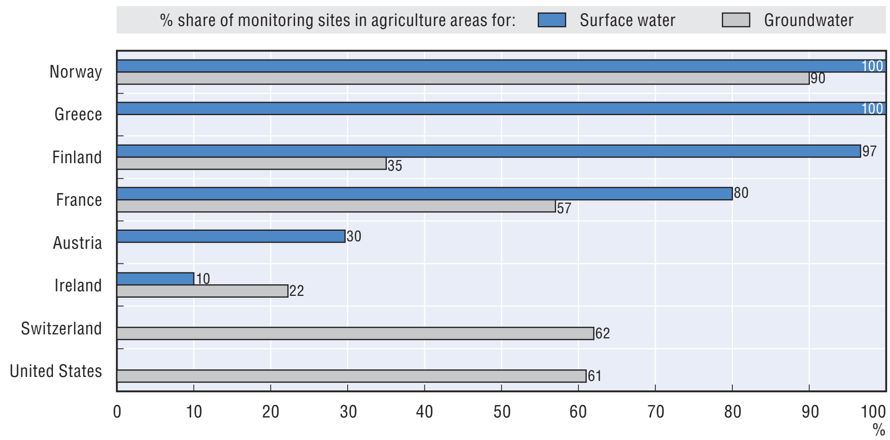
areas suffer from sediment and nutrient loadings (Figures 9.5, 9.6 and 9.9). In terms of the environmental health of the Great Barrier Reef (GBR), recent research indicates that quantities of sediment, phosphorus and nitrogen entering the GBR have been increasing, with agriculture

Figure 9.8. **Agricultural areas where one or more pesticides are present in surface water and groundwater, OECD countries, 2000-10**



Notes: Countries are ranked in descending order of highest share of pesticide presence in surface water.
Data for surface water are not available for Switzerland and the United States. Data for groundwater are not available for Austria and Greece.
For surface water, the figures presented refer to the 2005-07 average for Austria; the 2008-10 average for Finland and Ireland; the year 2002 for France and Switzerland; the year 2000 for Greece; and the year 2010 for Norway.
For groundwater, the figures presented refer to the 2003-05 average for Finland; the year 2002 for France and United States; the 2007-09 average for Ireland; the year 2009 for Switzerland; and the year 2010 for Norway.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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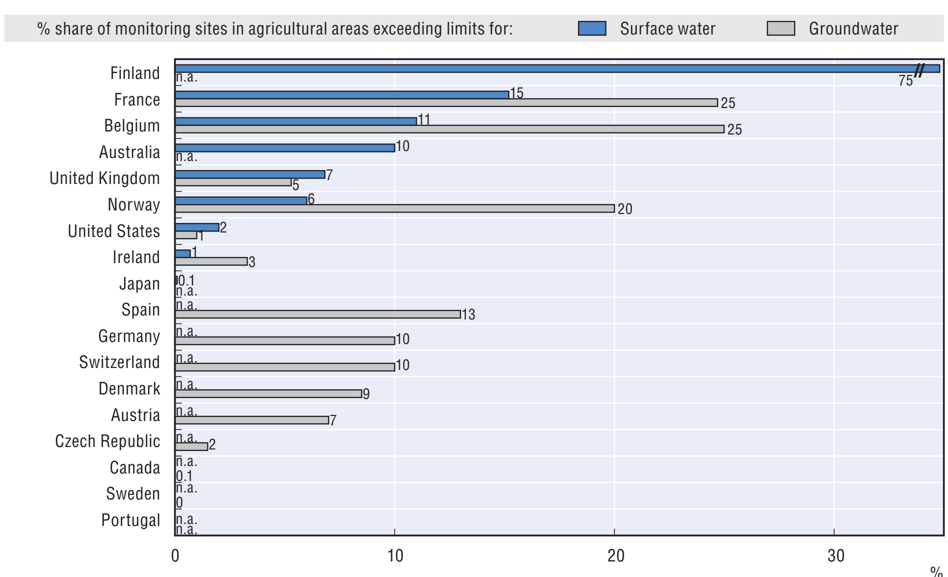
Figure 9.9. **Agricultural areas where pesticide concentrations in surface water and groundwater exceed recommended national drinking water limits, OECD countries, 2000-10**



n.a.: not available.
Notes: Countries are ranked in descending order of highest share of monitoring sites exceeding pesticides drinking water limits for surface water.
For surface water, the figures presented refer to: 2002 for Australia, Belgium, France, Norway and United States; 2004 for Ireland; average 1998-2005 for Japan; and average 2005-07 for United Kingdom.
For groundwater, the figures presented refer to: 2000 for Denmark and Germany; 2002 for Belgium, Canada, France, Norway, Spain, Sweden, United Kingdom and United States; 2003 For Czech Republic; average 2007-09 for Ireland; 2009 for Switzerland; and average 2008-10 for Austria.
Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

StatLink http://dx.doi.org/10.1787/888932793167 a key contributor to water quality issues in the GBR (Rolfe and Windle, 2011). But given the lack of a national monitoring system it is difficult to assess national trends in water quality related to agriculture (State of the Environment 2011 Committee, 2011).

Overall water is of high quality in **New Zealand**, but the quality of a number of lowland rivers and streams is causing concern. There are expensive restoration clean-ups going on in some iconic lakes and there are questions over the state of groundwater. At a national level, diffuse discharges now greatly exceed point source pollution (e.g. sewage treatment works) (Figure 9.1). Around 64% of monitored lakes in pastoral landscapes are classed eutrophic or worse (Ballantine and Davies-Colley, 2009; Land and Water Forum, 2010). Similarly groundwater quality has been deteriorating, with one third of sites monitored between 1995 and 2008 recording increasing nitrate levels (Daughney and Randall, 2009).

Nutrient pollution from nitrates and phosphorus

Agriculture is often the major source of emissions of nitrates and phosphorus into surface water and groundwater across OECD countries (Figures 9.1, 9.2 and 9.6). With point sources of water pollution (i.e. industrial and urban sources) falling more rapidly than for agriculture over several decades, and effectively controlled in most situations, the share of agriculture in nutrient pollution into water systems has been rising even though absolute levels of pollutants have declined in many cases (OECD, 2008; 2012).

Trends in the contribution of nitrate and phosphorus to surface water are mixed over the period 1995 to 2009, however, this conclusion is based on a very limited number of OECD countries (Figure 9.2). For groundwater the information on trends are even more limited, with only **Austria** providing an indication of trends over time (Figure 9.7). In terms of the number of monitoring sites in agricultural dominated areas that exceed recommended drinking water limits for nitrates and phosphorus in surface and groundwater, evidence shows this tends to be lower for surface water (Figure 9.5) compared to groundwater (Figure 9.6).

OECD agriculture is also a significant source of emissions into marine waters (Figures 9.3 and 9.4). Estuarine and coastal agricultural nutrient pollution has been an important contributory factor in some regions leading to eutrophication and the creation of algal blooms (i.e. “red tides” or “dead zones”). This has caused extensive damage to marine life, including commercial fisheries in coastal waters adjacent to **Australia**, **Japan**, **Korea**, the **United States** and **Europe**, mainly the Baltic, North Sea, and Mediterranean (Diaz et al*.*, 2012; OECD, 2012).

In the **Baltic Sea** catchment area, for example, the major anthropogenic source of waterborne nitrogen is diffuse inputs, mainly agriculture (HELCOM 2009; Malmaeus and Karlsson, 2010). They constitute 71% of the total load into surface waters within the catchment area. Agriculture alone contributed about 80% of the reported total diffuse load. The largest loads of phosphorus originated from point sources (56%), with municipalities as the main source, constituting 90% of total point source discharges in 2000, with 44% from diffuse sources, such as agriculture. For some Baltic countries, such as **Finland** and **Sweden**, agriculture is the major contributor of phosphorus into the Baltic.

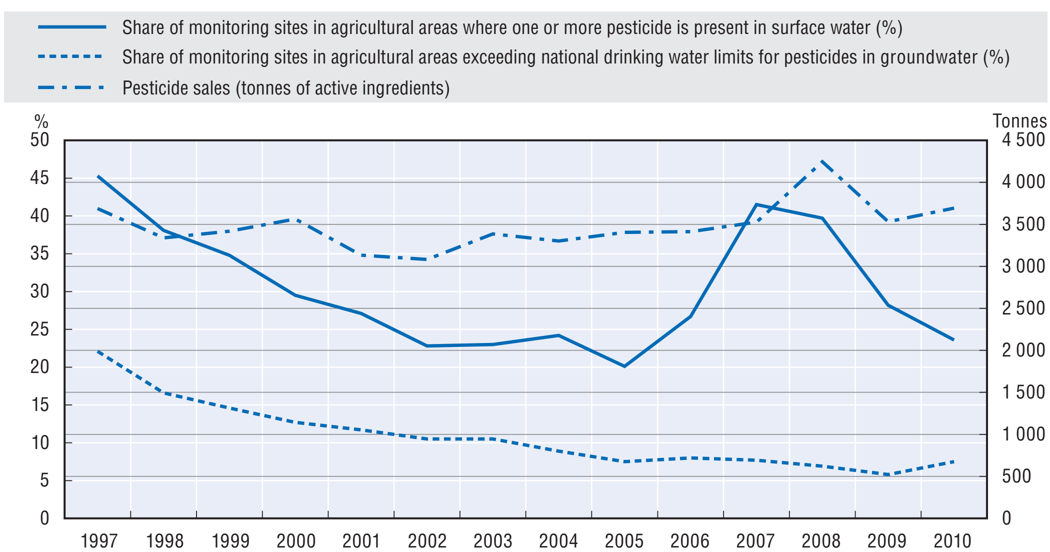
Similarly the **Gulf of Mexico’s** hypoxic (dead/eutrophic) zone, first detected in the 1970s, has increased in size substantially, largely as a result of agricultural nutrients washed from the Mississippi into the Gulf (OECD, 2012). The **United States** National Oceanic and Atmospheric Administration research shows that although the overall trend is for an increase in the area of the Gulf hypoxic zone, the area of the zone varies annually according to climatic conditions (Devine, Dorfman and Rosselot, 2008; Rabotyagov et al., 2010).

Pesticide pollution

The presence of pesticides in surface water and groundwater is widespread across OECD countries, with some countries having over 60% of monitored sites found to have one or more pesticide present in surface water and groundwater (Figure 9.8). But less than a third of OECD countries monitor pesticides in water systems. Caution, however, is required when linking trends in pesticide use to water pollution, as different pesticides pose different types and levels of risks to aquatic environments and drinking water (OECD, 2008).

There are a number of OECD countries where over 10% of monitoring sites in agricultural areas have pesticide concentrations in surface water and groundwater in excess of recommended drinking water limits (Figure 9.9). But as with other agricultural water quality indicators, the number of OECD countries monitoring pesticides in water systems is limited, as are time series data, although data for **Austria** reveals the close link between trends in pesticide sales tracking trends in pesticides detected in surface water, although responses might be delayed for groundwater (Figure 9.10).

Figure 9.10. **Agricultural areas where one or more pesticides are present in surface water and where pesticide concentrations in groundwater exceed recommended national drinking water limits, Austria, 1997-2010**



Source: OECD Agri-Environmental Indicators Questionnaire, unpublished.

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Another concern with pesticide pollution of water bodies relates to highly persistent and toxic pesticides such as DDT. In most cases in OECD countries such pesticides have been banned for many decades, but are, nevertheless, still being detected at levels harmful to aquatic organisms. This is the case, for example, in **France**, the **United States**, and **Mexico**, although in the latter country the ban on such pesticides was more recent (OECD, 2008). Pesticides are also reported as a common pollutant in coastal waters for some countries (**France** and **Mexico**), with risks to human health from fish consumed from these waters, of particular concern for **Mexico** where pesticide sales have been increasing over the past 20 years (Figure 5.1) (OECD, 2008).

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