Monitoring effectiveness of the EU Nitrates Directive Action Programmes: Approach by the Walloon Region (Belgium)

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Abstract Wallonia (the Walloon Region of Belgium) has implemented the Nitrates Directive by designating four vulnerable zones (15% of the territory) and introducing an Action programme at the start of November 2002. The Action programme entails various means of reducing the risks of the pollution of water by nitrate: (a) struggle against nitrate losses in fields using a range of good agricultural practices, including certain restrictions on the use of fertilisers (quantities, time periods, soil conditions, etc.), (b) keeping a balance on each farm between the organic nitrogen produced and utilisation capacities on agricultural land, (c) adapting storehouses for livestock effluent to a capacity of 6 months and perfect watertightness, and (d) promoting transfers of livestock effluent between farms in excess and farms which still have a way of using it on their land. In Wallonia, nitrate-related problems are obvious in several groundwater bodies and the development over the past 30 years is worrying. In general, the average pollution level is of agricultural origin. On the other hand, the pollution peaks observed in several places come often from domestic sewage. The aims of the measures taken within the framework of the Nitrates Directive are therefore above all to contain the nitrogen pressure from agriculture within sustainable limits and to remove point source pollution at the scale of large hydrographic basins. For more local cases, additional legislation deals specifically with the direct protection of water catchments against nitrate and also all other potential pollutants.

1 INTRODUCTION

1.1 General

The geology and land use of the Walloon territory is varied for such a small area. All agriculture is intensive there, but significant differences exist between the regions and between farms in the same region.

Overall, the nitrate concentration in groundwater is far below 50 mg l^{-1}. In vulnerable aquifers, concentrations above 50 mg NO_3 l^{-1} appear in less than 10% of the monitored sites. However, the trend is worrying. Surface water eutrophication is only present in some much-localised situations. The nitrogen pollution observed comes rather from isolated poor agricultural practices and not from a structural surplus at regional level. It is also sometimes due to discharges of domestic wastewater.

The programme to combat nitrate of agricultural origin is therefore mainly focused on prevention, with a view to the sustainable management of nitrogen in agriculture. There are four vulnerable zones (designated in 1994 and 2002), a code of good agricultural practices and one single action programme for these four zones. The measures provided for in this unique programme are designed to meet the need to limit isolated and/or temporary cases of waste discharge, while limiting spreading to under 170 kg of organic nitrogen per ha on average on the territory as a whole.

Preliminary scientific studies have not proven that it was necessary to take account of the specificities of each vulnerable zone in this first action programme. A total of 26 pilot sites are spread over each zone in order to check the effects of the action programme and to adapt it to each zone if necessary. The action programme started off in October 2002; it is developed on three complementary levels: the field, the farm and the Walloon Region.

In the field, the objectives are to limit nitrate leaching in winter and to prevent losses by leaking. The farmer must respect a number of good agricultural practices, particularly time periods for spreading manure and slurry, maximum doses of organic and mineral nitrogen per crop and per year, distances in relation to waterways, storage conditions for field manure, etc.

At farm level, the objective is to limit the pressure of organic nitrogen on agricultural land and to fight against point source pollution. The farmer must make sure to always take a soil-based approach, i.e. respect the balance between the organic nitrogen to be spread (coming from the herd or from the importation of matter) and the total spreading capacity on crops and pastures (calculated by multiplying the surface areas by maximum permissible levels according to the zones). A limited derogation may be granted if the farmer undertakes to follow a "Quality Approach" with very close surveillance and the implementation of specific techniques proving his control of nitrogen. Again at farm level, the farmers must be sure to have a sufficient watertight storage capacity for manure, slurry and other silage effluent.

Finally, on the scale of Wallonia, the objective is to optimise the utilisation of organic fertilisers between farms. The action programme promotes transfers of livestock effluent between farms in surplus and those with low organic amounts.

1.2 Description of natural factors influencing nitrate occurrence

The climate of the Walloon Region comes under the Atlantic temperate climate. Annual rainfall amounts to 15,000 million m³ (887 mm $year^{-1}$), 550 (33 mm $year^{-1}$) of which refill the subsoil water, 7950 (470 mm $year^{-1}$) sustain the surface waters, and 6500 (384 mm $year^{-1}$) are reabsorbed into the atmosphere by evapotranspiration. Several differences can be observed between sub-regions (Fig. 1). For all sub-regions, the refilling of the groundwater layers mainly takes place between October and March.

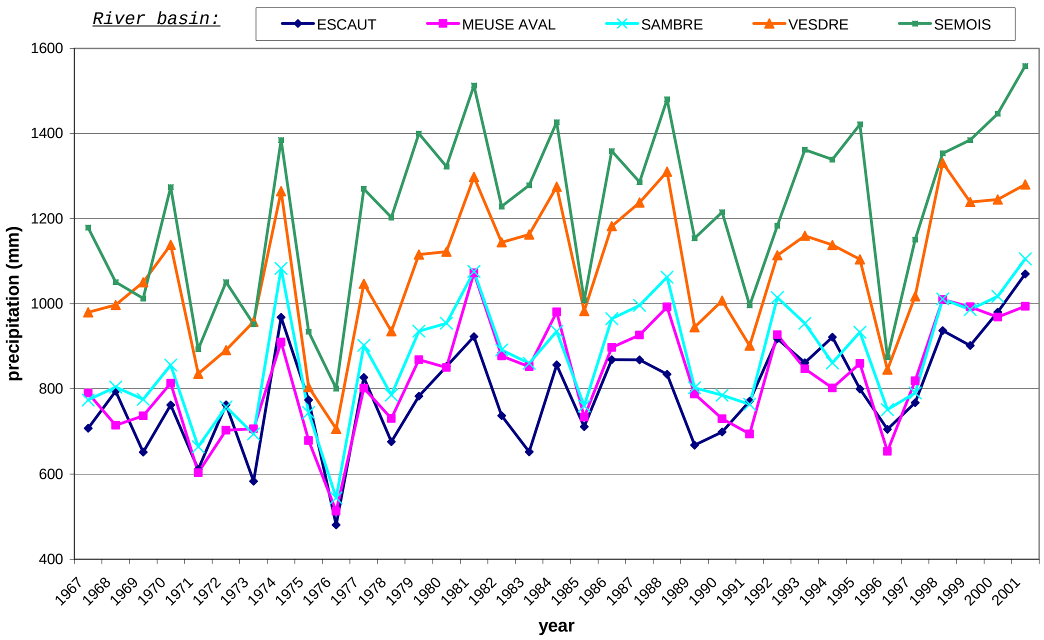


Fig. 1 Average annual precipitation (mm) of some stations in the Walloon region in the 1967-2001 period.

The geology and the soil types are rather varied: more than 60 associations of different soils are listed over the 17,000 km² of Wallonia, from deep sandy silt soils to very superficial clay-like, stony soils. When crossing the Region from the north to the south, one first sees wide agricultural plains with many crops and little pastureland, followed by a landscape of small valleys in which crops, pastures and forests alternate, ending finally in the high Ardennes plateau that is mainly covered by forest and pastureland, with deeper valleys. Within these large zones, a distinction can be made between eight to ten agricultural regions with homogenous soil, climatic and ecological characteristics.

In the subsoil, several types of aquifers are to be found (from north to south and from west to east – see also the corresponding colours on Fig. 6):
- the sands of the Yperian-Thanetian, of the Brusselian and the Landenian (yellow);
- the chalk of Mons, Brabant, Hesbaye and Pays de Herve regions (green);
- the limestone of the Tournaisis, of the central part of the Namur synclinorium, of the Dinant synclinorium and the Vesdre mounts (blue);
- the shales and sandstone aquifer in the Dinant synclinorium and in the Ardenne mounts (grey);

- the jurassic sands and sandstone in the South of the Luxembourg province (pink);
- the gravels of the Meuse and other alluvia in the large valleys (orange).

The most used groundwater bodies are situated in the unconsolidated strata and the coherent rocks of the north and the centre of Wallonia. Overall, these reservoirs are situated deep in the ground and are covered by loams or sands. The nitrogen transfer times measured and modelled between the surface and the aquifer amount to 5 to 15 years according to the place.

In the more superficial aquifers, which are less used for drinking water production, the transfer times scarcely exceed 3 years.

1.3 Description of human factors influencing nitrate occurrence

Global information on land use

The ten agricultural regions of Wallonia are characterised by pedological and climatic parameters (Fig. 2); two categories of regions can be distinguished:

- regions used for pastureland and fodder crops: the Ardennes, Famenne, the grassland region of Liège, the Jurassic region, the Haute Ardenne and the grassland region of Fagnes (pastureland represents between 70% and 90% of the agricultural area);
- regions used for cereals and industrial crops (sugar beet and potatoes): the silt region, the Condroz and the sandy silt region.

In the regions used for pastureland, forests take up an average of over 50% of the total area.

Fig. 2 Map of the agricultural areas in the Walloon Region.

Main crops (year 2000, unless otherwise indicated)

The utilised agricultural area (UAA) in the Walloon Region is 757,000 ha, that means 45% of the territory. Forests cover 32% of the territory. The rest is occupied by settlement areas, economic activity zones and road infrastructure. The UAA comprises 50% pastureland and 50% arable land, see Table 1 (MRW – CSWAAA, 2000).

Between 1985 and 2000, the UAA decreased by 1.7%. It reached a minimum level in 1992, and has since undergone a slight increase.

Table 1 Surface area (ha), percentage of utilised agricultural area and development of the area between 1985 and 2000 (%) for the main commodities in the Walloon Region.

		Surface area (ha)	UAA (%)	Development 1985-2000 (%)
Pastureland		378859	50.1	- 3.2
	Permanent pasture	326075	43.1	- 15.4
	Temporary pasture	52785	7.0	+ 795.4
Fodder crops		55612	7.3	+ 14.8
	Silage maize	52295	6.7	+ 23.4
Main crops				
	Cereals	183675	24.3	- 16.9
	Sugar beet	56900	7.5	- 25.3
	Inulin chicory	11700	1.5	+ 8257.1
	Textile flax	8658	1.1	+ 64.5
	Rapeseed	4520	0.6	+ 89.4
	Potatoes	21527	2.8	+ 131.7
Horticulture				
	Vegetable crops	9898	1.3	+ 15.1
	Fruit crops	1438	0.2	+ 47.5
Fallow		17086	2.3	+ 7393.9 (*)

Maize cultivated for silage represents more than 90% of the area used for fodder crops other than pastureland (52,000 ha). In the Walloon Region, irrigable land areas are very limited: 5513 ha in 1997, i.e. 0.7% of the UAA. However, irrigable areas have undergone some raise since 1985 (+444 ha). They concern vegetable field crops in rotation with agricultural crops in the sandy silt and silt regions (MRW – DGRNE et coll., 2000).

Characteristics of agriculture (agricultural practices)

In 2000, the Walloon Region had 21,000 farms, 66% of which were professional and 30% occasional producers. Between 1985 and 2000 the number of farms decreased by 37%. Consequently, between 1985 and 2000 the average farm size increased by 57%. In 2000, the average agricultural area of farms in the Walloon Region was 36 ha (MRW – CSWAAA, 2000).

In 1999, farms were mainly technically and economically orientated towards the dairy sector (20% of farms), the beef sector (19%) and arable crops (17%). Arable crop farms are mainly situated in the silt and sandy silt regions and in the Condroz. Dairy specialisation predominates in the Haute Ardenne and the grassland region of Liège. The farming of livestock for meat is above all practised in the Ardennes, in the Jurassic region, Fagne and Famenne. Seventy-five percent of farms in the Walloon Region (16,000) have cattle (Table 2). The number of cattle has been decreasing since 1996 (-4.5%) following the BSE crisis.

Table 2 Livestock in the Walloon Region: animal numbers, production of nitrogen and development between 1985 and 2000.

		Number of heads (x1000) and development (% between 1985 and 2000)		Number of heads ha^{-1}	Total production of organic nitrogen (tonnes of organic nitrogen year^{-1})	Percentage of organic nitrogen production
		number	%			
Cattle		1480	+ 1.8	1.96	81775	93.1
	Dairy cows	273	- 38.8	0.36		
	Suckler cows	336	+ 168.3	0.44		
Pigs		317	- 4.5	0.42	3726	4.2
Poultry					1409	1.6
	Laying hens	900	+ 28.6	1.19		
	Broilers	3000	+ 499.3	3.96		
Other (*)					952	1.1

(*) Other = Sheep (304,580 kg org. N year^{-1}) + Goats (41,783 kg org. N year^{-1}) + Equidae (horses) (585,536 kg org. N year^{-1}) + Ostriches (3,424 kg org. N year^{-1}) + Suckler rabbits (16,589 kg org. N year^{-1})

The Walloon Region has 7800 dairy farms, in other words 37% of the total number of farms. Since 1985, the number of dairy farms has fallen by 57%. Only 6% of farms have pigs, in comparison to 20% in 1985. In the pig production sector, 50% of farms have less than 50 pigs and 80% less than 400 pigs per farm. Poultry production has undergone significant development over the past few years (MRW – CSWAAA, 2000).

Total organic nitrogen production on farms in the Walloon region totals 88,000 tonnes. The cattle stock produces 93% of this quantity of organic nitrogen, pigs 4% and poultry 2% (Table 2). This annual production corresponds to 116 kg of organic nitrogen per ha of UAA. This average value disguises the disparities specific to agricultural regions dominated by certain commodities. The percentage of livestock fodder in intermediary consumption (fertilisers, energy, feeding stuffs, others) is 31%.

Production of effluent and use of fertilisers

In terms of volume and apart from direct pastureland recovery, two-third of organic fertilisation in Wallonia is in solid form (manure, compost) and one-third is in liquid form (liquid manure and slurry).

The average mineral nitrogenous fertilisation is presented (Table 3) for the main arable crops in different agricultural regions (Agricultural Economic Analysis Division of the Walloon Region - Ministère des Classes Moyennes et de l’Agriculture, 2001)). These results consist of the arithmetical averages of the observations made over five consecutive financial years (1997-2001) on 2,500 farms (horticulture not included).

Table 3 Mineral nitrogenous fertilisation (kg N ha^{-1}) of arable crops in different agricultural regions; averages for the 1997-2001 period.

Agricultural regions	Sugar beet	Potatoes	Wheat	Silage Maize	Temporary pasture	Permanent pasture
Sandy silt	145	184	180	149	235	142
Silt	156	165	178	144	314	160
Condroz	161	160	182	134	238	115
Liège grassland	137	(x)	157	100	126	113
Famenne + Fagnes	188	125	172	126	125	78
Ardennes + Jurassic	(x)	(x)	138	116	106	59
Haute Ardenne	(x)	(x)	(x)	22	(x)	126

(x) Missing data: no observation in the sample or insufficient observed area

For assessment purposes, the calculations based on the method described by the Association for Research on Nitrogen Indicators (ARIA) have been made on 89 farms (Lambert et al, 2001) situated in the silt and sandy silt regions (Table 4).

Table 4 Annual nitrogen assessments for the main types of agricultural commodities (kg N ha^{-1}) in silt and sandy silt regions (plus/minus sign means standard deviation)

	Farm-gate balance	Surface balance
Crop + battery farming	219 ± 23	200 ± 36
Crop + dairy	225 ± 33	205 ± 41
Crop + dairy and meat	178 ± 32	153 ± 42
Crop + meat	113 ± 17	115 ± 24
Arable crops	63 ± 11	64 ± 10

1.4 Overview of monitoring networks

1.4.1 Monitoring for the identification of waters

Each year, the Walloon Region produces 400 million m³ of water for the public water supply. Of this, it exports around 150 million m³ to Brussels and Flanders. Eighty percent of this water comes from groundwater spread throughout the entire territory. There are 1600 water catchments (wells or springs) recorded, forming around 500 important production sites. The other 20%, produced from potentially potable surface waters, are located over the south of the region on nine water intake and treatment sites (five direct river intakes and four dam reservoirs).

If in addition to this we add the numerous bottled water producers and the agri-food industries supplied with drinking water from the aquifers, it is evident that groundwater is particularly valuable.

In the Walloon Region, all producers of potential drinking water are therefore first of all called upon to carry out a control of the water taken and to transmit the results to the Administration (DGRNE, Direction générale des Ressources naturelles et de l'Environnment –Directorate General for Natural Resources and the Environment – Water Division). In a large majority of cases (with the exception of water mixes or treatments that affect nitrogen concentrations), the analyses of distributed or bottled water (obligatory in accordance with the Directive on water for human consumption) are therefore likewise used to monitor nitrates. The range of parameters (NO_3 + NO_2 +

NH_4) is required to control possible cases of oxidation reduction caused in conveyances and during potabilization treatments (chlorination for example).

The DGRNE undertakes further monitoring in regions for which the data is insufficient, in aquifers (often superficial) that are scarcely used. Moreover, it of course manages the main part of the surface water monitoring.

1.4.2 Monitoring in vulnerable zones

In the Walloon Region, as far as water is concerned, there are no major differences between monitoring to identify vulnerable zones and monitoring to control them. Surveys of surface water are ongoing. For groundwater, the checks are more systematic and no derogations are granted to water producers for the implementation of analyses (NO_3 + NO_2 + NH_4).

However, concerning groundwater, the DGRNE sees to completing the network in the vulnerable zones in order to obtain sufficient coverage of the territory and the aquifers, particularly the superficial aquifers which are not used much by producers of potential drinking water.

This is for example how, in the eastern part of the vulnerable Brusselian sand zone (1260 km^2), remarkable springs are included in the network (equipped and accessible to the public, continual flow).

For the vulnerable zone of Hesbaye chalks (293 km^2), which has a relatively homogenous aquifer, the results transmitted by producers for 14 sites (in fact 21 catchments) are deemed to be insufficient.

For the small vulnerable zone of Comines-Warneton (61.4 km^2), sixteen traditional wells belonging to farmers or private persons have been exclusively chosen in agricultural areas or in rural settlements.

In order to survey the Berwinne and Gueule basins (200 km^2), east of Liège, where the land use is quite homogenous (mainly pastureland), a network of 32 points has been set up; this network, which is represented in Fig. 3, takes account of the complexity of the main aquifer of Cretaceous while ensuring good territorial coverage.

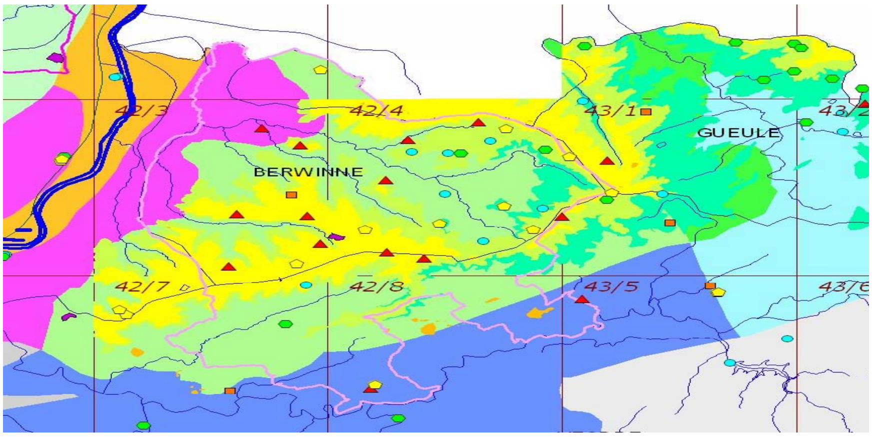


Fig. 3 Example of a surveillance network for the Berwinne and Gueule basins

For the Brusselian sand (hydrogeologically homogenous aquifer but divided up by watersheds) and the vulnerable South Namur zone (composed of several adjoining aquifers with varying characteristics), a selection must be made from among the data transmitted because the survey sites are many and badly distributed. Apart from geographical frequency, the selection criteria are the volume of the water catchments, the need to measure the impact of diffuse, non-point source pollution and the presence of protected zones (Natura 2000 zones for instance, which are presented on www.natura2000.wallonie.be).

This selection of sites then makes it possible to calculate a rather robust average indicator that is part of the guidelines for monitoring the effectiveness of the Action programmes. The development of this indicator is represented in Fig. 4 for the three largest vulnerable zones (NVZ).

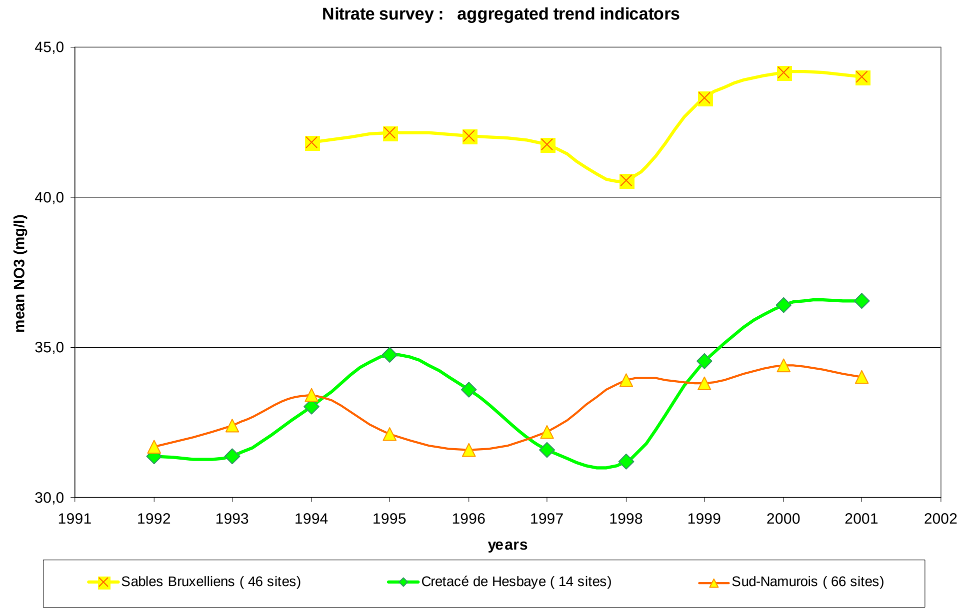


Fig. 4 Aggregated results from the nitrate survey for the three largest NVZ.

For the Crétacé de Hesbaye and, to a lesser extent, Brusselian sand, the unfavourable development observed in recent years is clearly related to the development of the aquifer level. The "Programme-Action Hesbaye" study (Dautrebande *et al.*, 1996) has in fact clearly shown that the infiltration of nitrate is delayed in the silt cover and in the non-saturated chalk zone. Consequently, the effect of the action programmes cannot be measured directly in the water catchments and will take several years before becoming evident.

With regard to the surveillance of the groundwater, the justified particularity in the Walloon region of calling upon numerous producers of drinking water for nitrogen monitoring purposes allows to save substantial resources but brings problems of representativity for the sites measured in relation to agricultural pressure and of continuity in the transmitted results.

The administration, which is supported by the company Aquawal S.A. (the association of operators of the water cycle), manages this by issuing frequent reminders, using an electronic transfer file of entirely precise format, and by taking over the monitoring of abandoned and particularly well situated water catchments.

1.4.3 Monitoring of changes in agricultural practices

With regard to the changes in agricultural practices, several indicators have been established. Among these, the following indicators are measured each year for all of the farms in the Walloon Region, which are discussed in detail in § 2.2.4. :

a) the soil linkage rate of the farm;
b) the number of effluent exchanges between farms.

On farms that are involved in the Quality Approach (Q.A.), other indicators are also measured:

c) the application of environmentally friendly agricultural practices (winter soil coverage, grass strips, integrated fertilisation techniques, etc.);
d) the nitrogen farm gate balance and surface balance;
e) the soil profiles of nitric nitrogen concentration, drawn up in the autumn on five parcels of land.

Finally, technical information meetings are organised regularly. The chosen indicator of access to the farmers' information is:

f) the rate of attendance at these meetings.

This annual monitoring makes it possible to estimate changes in agricultural practices. The effect of these changes could be estimated on the scale of the parcel thanks to the three indicators monitored on the farms involved in the Q.A.

2 EFFECT MONITORING

2.1 Strategy for effect monitoring

The Walloon Region bases its monitoring strategy on two aspects: the development of water quality, and the monitoring of the changes in farm management practice. Tendency indicators are established in order to analyse the improvement or worsening of nitrate pollution of agricultural origin.

The development of water quality is of course the ultimate measure of the efficacy of the Action programme. It is thus studied using the monitoring network of the DGRNE and the water production companies, and especially the nitrate survey. However, this measure in itself only reveals part of the efficacy because, on the one hand, nitrate pollution also comes from other sources (domestic wastewater) and on the other hand, there is often a delayed "response" of several years or decades between the surface and the groundwater.

The Action programme therefore provides a set of specific indicators for the monitoring of agricultural practices. Among these indicators, some are result-orientated and measure the effect of agricultural practices, such as the survey of agricultural soils, or deal with the nitrogen farm gate and surface balances. Other indicators are directed at the methods employed by farmers, such as the soil linkage rate of the farm and the surveillance of transfers of organic fertilisers between farms, or, in a different vein, the effective participation in technical information sessions organised by the supervisory services, see § 2.2.4.

2.2 Detailed technical description networks used for effect monitoring

2.2.1 Groundwater

Since 1994 when the nitrate survey was made obligatory for producers of potential drinking water by the government, 88 companies have carried out 45,000 analyses of 1232 water catchments and communicated the results to the DGRNE (figures compiled on 01/01/2002).

The minimum control frequency is three analyses in the course of the year, but this increases depending on the volume produced according to annex IIb of Directive 80/778/EEC (European Consilium, 1980).

If nitrates exceed 25 mg NO_3 l^{-1}, the water producer is generally obliged to transmit results each year, except in the Ardenne region, where the agricultural pressure is low. The postponement of the survey every 8 years provided for by the Directive for levels below 25 mg NO_3 l^{-1} has only been granted for some mineral or thermal springs.

Moreover, the records of available data in water companies have been given to the Administration and the earliest analysis dates back to 1957, as revealed by the record of a well situated in Waremme in the Hesbaye chalks (Fig. 5).

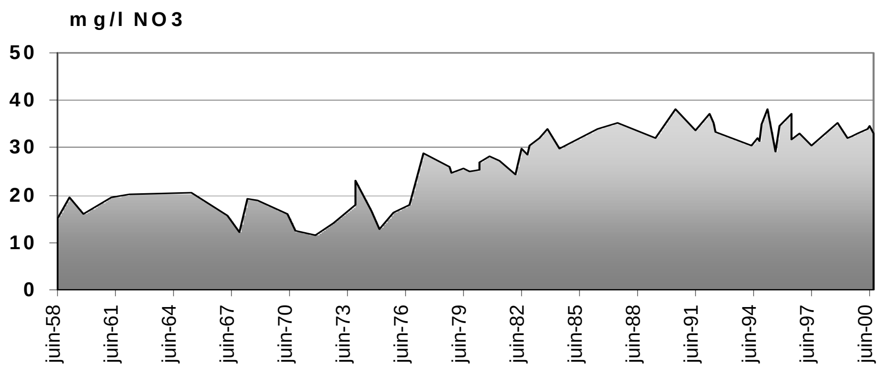


Fig. 5 Trend in the Hesbaye Chalk – Waremme catchment.

On its part, the DGRNE meticulously carried out between 1993 and 1995 a considerable nitrate survey on 491 springs and household or farm wells that were not used for the production of drinking water. These data are used as a basis for the selection of additional survey sites, particularly in the existing vulnerable zones and for few abstracted aquifers.

Thus, 29 sites situated in agricultural areas were taken for the cretaceous aquifer in Pays de Herve (East Wallonia) and 16 others for the Yperian-Thanetian sands of Mouscron-Comines (West). Two samples are taken from them each year.

The type of aquifer (phreatic/confined) and whether it holds a vulnerable or assimilated zone are indicated in Table 5 above. For phreatic aquifers, apart from the numerous springs and tunnels, the depths of the water catchments generally varied between 10 and 50 metres, with the aquifer level generally varying between 5 and 20 metres. In the more superficial aquifers, the piezometers used were generally active wells (in order to avoid pumping and to benefit from a preliminary homogenisation of the aquifer). Numerous traditional wells less than 5 meters in depth were discarded as far as possible during the sampling process, in order to avoid sub-surface flows and perched aquifers.

Table 5 number of sites regularly sampled grouped according to large water bodies (a total of 870, i.e. an average density of 1 site per 20 km^2).

Groundwater body	Typology	Including a vulnerable zone ?	Total sites	Mean NO3 value (2001)
Superficial thanétian sands	Phreatic	Yes	16	57,5
Brusselian and landenian sands	Phreatic	Yes	86	44,9
Chalk of the Pays de Herve	Phreatic	Yes	32	39,5
Hesbaye chalk	Phreatic	Yes	21	34,2
Aquifers of the Vesdre mounts	Phreatic	Yes	11	30,9
Dinant shale-sandstone mounts	Phreatic	Yes	72	30,6
Dinant devonian limestone	Phreatic	Yes	35	29,9
Mons bassin chalk	Phreatic/Confined	No	49	27,4
Dinant carboniferous limestone	Phreatic	Yes	91	26,8
Meuse gravels	Phreatic	No	31	19,0
Brabant confined chalk	Confined	No	13	17,1
Brabant cambro-silurian platform	Confined	No	10	16,0
South Luxembourg jurassic aquifers	Phreatic/Confined	No	49	13,2
Ardenne platform and shale-sandstone mounts	Phreatic	No	279	10,9
Limestone of northern edge of Namur basin	Phreatic/Confined	No	61	10,7
Carboniferous limestone of Tournaisis	Confined	No	14	6,7
total for Wallonia			**870**	

Figure 6 shows the distribution of the measured sites as far as groundwater is concerned. The next DGRNE investigations (survey in 2004) will deal in particular with the (agricultural) south of the Mons basin cretaceous aquifer (red points on the map).

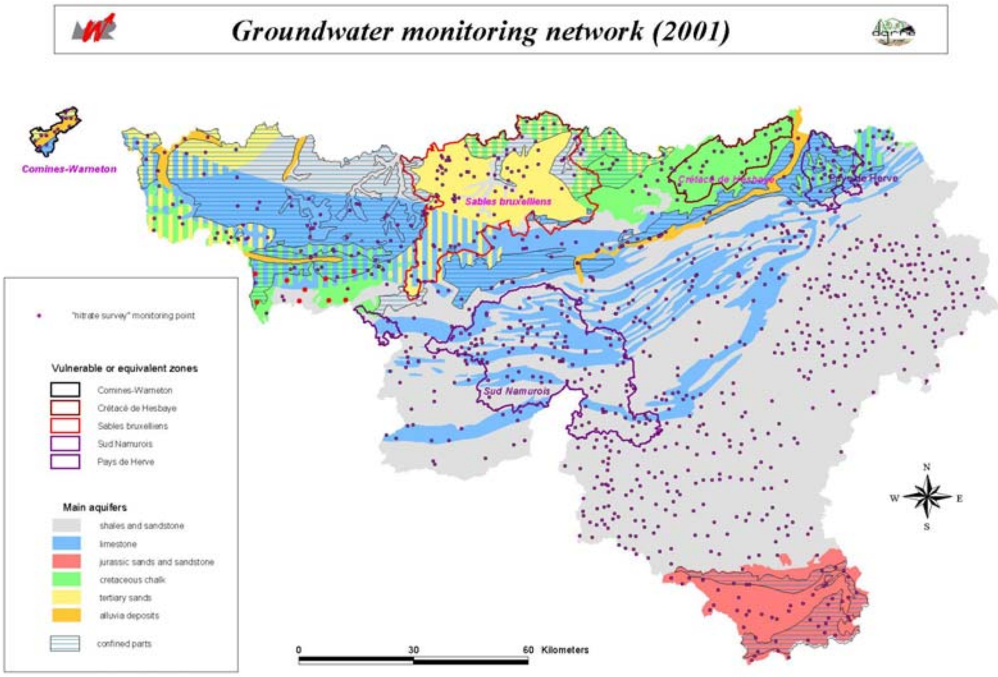


Fig. 6 The groundwater monitoring network, Nitrate Vulnerable Zones, and main aquifers in the Walloon Region.

Finally, it must be pointed out that since 1994, around one hundred water catchments have been abandoned following restructuring of water production or qualitative problems (15 of which were due to excessive nitrate content and not only due to agricultural activities). For the most relevant of them (agricultural area, unconfined aquifer), monitoring was then taken over by the DGRNE with the agreement of the producer, so as to maintain surveillance and to continue with the observation of the tendencies on these particularly representative sites.

2.2.2 Surface water

In the Walloon Region, the network for measuring the quality of the surface waters is managed by the DGRNE and, since 1993, the operational side has been entrusted as an assignment to the ISSeP (Institut Scientifique de Service Public - Scientific Institute of Public Service).

This permanent network is composed of 180 stations divided over all of the Walloon watersheds. In 2003, 160 points were sampled once a month and 20 points on a bimonthly basis. The stations controlled the most frequently are situated on the two rivers (the Meuse and the Escaut) and at the point of confluence of their main tributaries.

Nitrate and also nitrite and ammoniacal nitrogen are measured at all of the points in the network. At around 80 stations, all of the nitrogenous parameters are measured (Kjeldahl nitrogen, ammoniacal nitrogen, nitrite and nitrate) or calculated (organic nitrogen and total nitrogen).

The network –presented in Fig. 7– offers a spatial coverage of 1 point for 100 km^2 of territory.

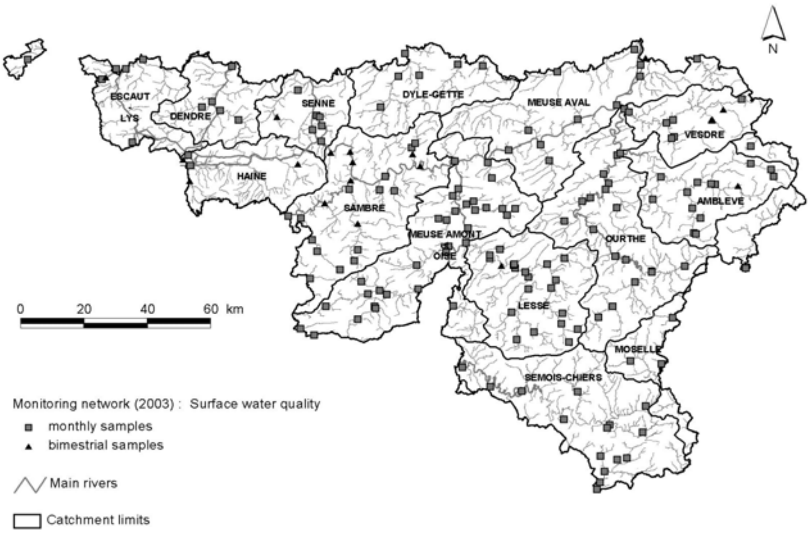


Fig. 7 The surface water monitoring network and catchments in the Walloon Region.

In the Walloon region, the upper lakes of the Haute Ardenne, generally located in natural areas or in zones subject to very low anthropogenic pressure, do not show contamination by nitrate, as demonstrated by the analyses transmitted by the water producers.

The intakes of potential drinking water in rivers, for example in the Meuse in Lustin or the Ourthe in Nisramont, are controlled at high annual frequencies. Figure 8 shows the monthly nitrate averages calculated for the Ourthe in Nisramont on the basis of daily samples.

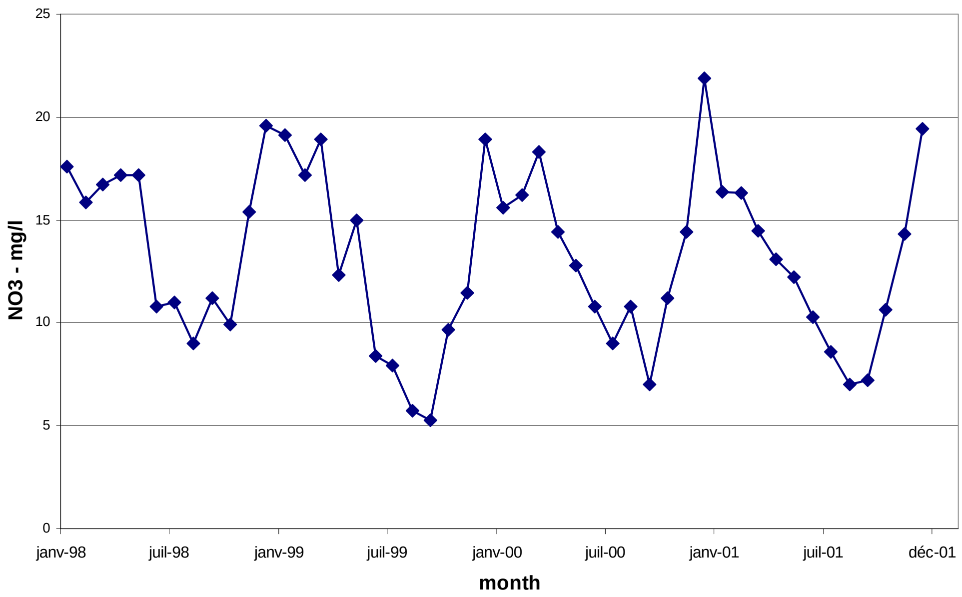


Fig. 8 NO_3 time series in the Nisramont reservoir (Ourthe River).

2.2.3 Eutrophication

The Walloon Region has only three lakes of over 1 km^2. In the largest, which is called Complexe des barrages de l'Eau d'Heure and with a total surface area of 5.9 km^2, significant eutrophication has been observed, with the development of cyan bacteria. A study has been planned to investigate the phenomenon and to pinpoint both its domestic and agricultural origin.

Most of the lakes in the Walloon region are bathing zones and are therefore monitored weekly during summer (microbiology and visual control).

The following relevant parameters are regularly measured on the quality measurement network for surface waters (rivers): NO_3, NH_4 and N-Kjeldahl, chlorophyll-a, P-total, O-PO_4, dissolved oxygen (daytime) and DBO5.

It is first of all important to calculate the loads emitted per watershed and particularly those exported to Flanders and the Netherlands, and thus towards the North Sea.

The limnigraph stations take daily measurements of the water flow rates close to the main sampling stations; Fig. 9 shows the amounts of NO_3, total-nitrogen and total-phosphorous estimated for the Dyle basin upstream from the Wavre urban sewage works station (area predominantly agricultural in nature and located in vulnerable zone). They are obviously conditioned by the rainfall intensity also measured by the IRM (Institut Royal Météorologique - Royal Meteorological Institute) in each basin, which has been particularly unfavourable in recent years.

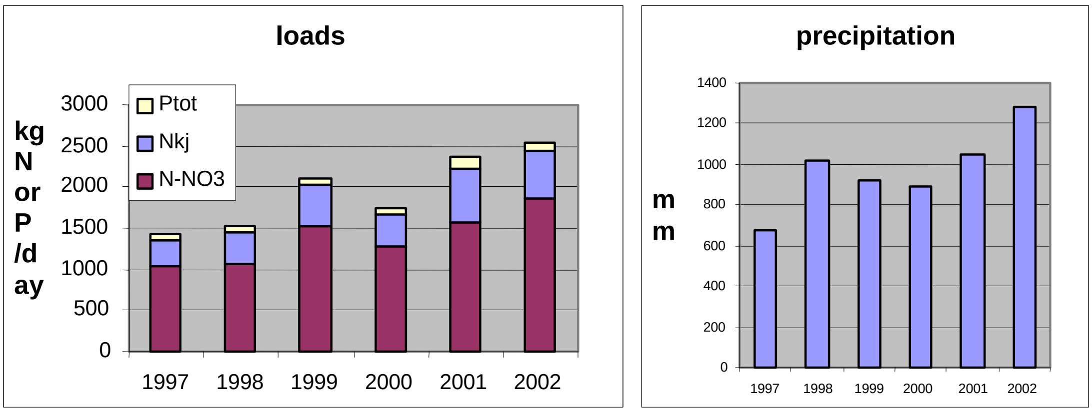


Fig. 9 N and P loads at the outlet of the Dyle River versus rainfall.

With regard to actual eutrophication, the summer averages in chlorophyll-a confirm that the phenomenon is rather limited in waterways in the Walloon region (those affected are some canals and rivers deficient in oxygen, although their nitrate content is generally converted into ammonium).

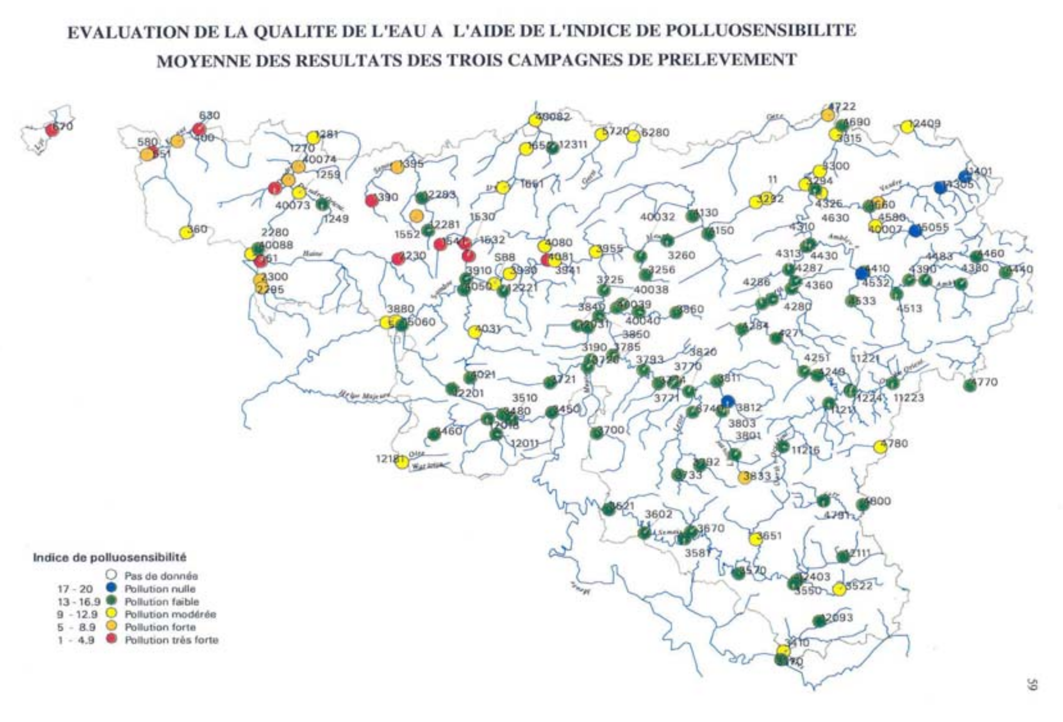
Within the framework of the International Commission for the Protection of the Meuse, the nitrogenous, phosphorous and chlorophyll parameters are controlled two times a month between March and October at the two stations selected to survey eutrophication.

For phosphorous, an index varying between 0 and 100 (best quality) is calculated using the following quality grid (see Table 6, source: SEQ-EAU France, 1999) applied to the measured annual 90 percentiles.

Table 6 eutrophication index for phosphorous matters.

Eutrophication level:	I	II	III	IV	V	Unit
SEQ-EAU index	>80	80-60	60-40	40-20	<20	
Ortho-phosphates	≤ 0.1	≤ 0.5	≤ 1	≤ 2	> 2	mg/l PO_4
Total phosphorous	≤ 0.05	≤ 0.2	≤ 0.5	≤ 1	> 1	mg/l P

This indicator of the alteration in “phosphorous matter”, in the same way as that concerning “nitrogenous matter” is strongly correlated to the “diatoma” indicators such as the IBD (Diatom Biological Index; AFNOR NF T 90-354 standard , 2000) or the IPS index (Pollution Sensitivity Indicator; Coste, 1982). These two biological indicators, based on the diatoma, which are unicellular microscopic algae belonging to the periphyton of the waterways, work together with chemical analyses and other bioindicators (benthic macroinvertebrates, etc.) to allow a reliable estimation of the quality of the surface waters (in particular of eutrophication). The two maps of Fig. 10 provide a convincing demonstration of this (acknowledgements to Prof. J.P. Descy of FUNDP in Namur, and D.Wylock, attaché at DGRNE).



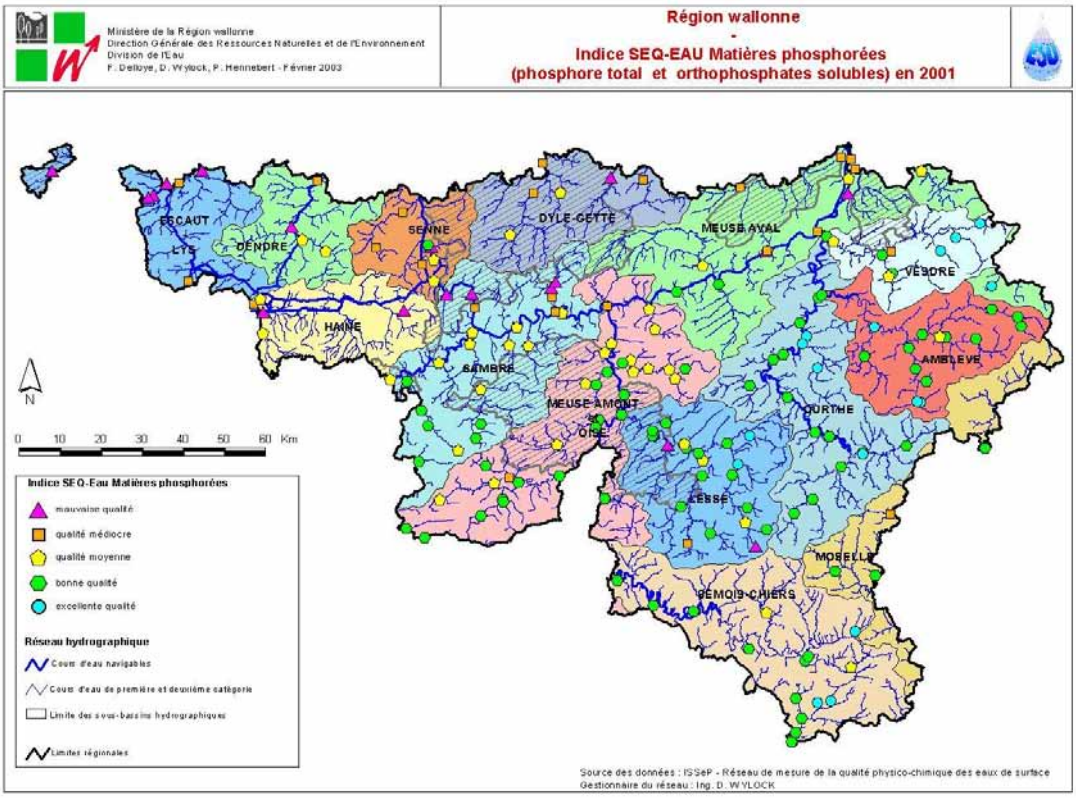


Fig. 10 Surface water network: comparison between the Diatom Biological Index (upper map) and the SEQEAU Phosphorus matter Index (lower map).

2.2.4 Agricultural practices

Several indicators have been developed to monitor the change in agricultural practices and its consequences on the nitrogen flows and residues in the soil in autumn. Three groups of actors are involved in the implementation of the Action Programme and in the follow-up of these indicators. These are:

a) the Directorate-General of Natural Resources and the Environment (DGRNE) of the Ministry of the Walloon Region (M.R.W.);
b) the Directorate-General of Agriculture (DGA) of the M.R.W;
c) Nitrawal.

Nitrawal is an association composed of 15 agricultural advisers supported by:

– the two agronomic universities (University Faculty of Agronomic Sciences of Gembloux and Université Catholique de Louvain-la-Neuve);
– the company of operators of the water cycle (Aquawal S.A.);
– a professional agricultural organisation (Fédération Wallonne de l'Agriculture - FWA).

Six indicators monitor the change in agricultural practices and its consequences; they are discussed in the following :

1. The first indicator is the soil linkage rate (SL) of the farm. It is calculated annually by the DGRNE for each farm in the Walloon region:

An SL higher than 1 means, that the farm is considered to have an excess of nitrogen production in relation to its utilisation capacity.

The DGRNE and the DGA manage two databases that contain sufficient information for the calculation of the nitrogen quantity produced by the livestock on each farm (on the basis of nitrogen production standards per animal category) and the utilisation capacity for this nitrogen.

In the four vulnerable zones of the Walloon Region, the content of organic nitrogen cannot exceed 80 kg ha^{-1} annually on land under crops and 210 kg ha^{-1} on land under pasture. Outside these vulnerable zones, organic nitrogen content cannot exceed an annual amount of 120 kg ha^{-1} on land under crops and 210 kg ha^{-1} on land under pasture.

Year "1" of the implementation of the Action Programme in the Walloon Region is 2003. On the basis of the calculations carried out by the DGRNE, it appears that:

- 15% (3,000/20,000) of farms in Wallonia have an SL higher than 1;
- 1.5% (300/20,000) of farms in Wallonia have an SL higher than 2.

These percentages are also specifically measured in each vulnerable zone.

The farm with an SL above 1 has four possibilities of recovering a balance between production and the utilisation of its organic nitrogen:

a) reducing its organic nitrogen production by decreasing livestock numbers;
b) giving the excess amount of this organic nitrogen to another farm that can use it (cf. indicator 2);
c) boosting its utilisation capacity by increasing its manurable surface area or the proportion of pastureland under crop rotation;
d) becoming involved in the QA (cf. indicators 3, 4, 5).

2. The second indicator is the traceability of the effluent exchanges between farms, which relates to:
   - the quantities of organic nitrogen transferred between farms;
   - the number of contracts concluded.

The producer, whose farm has an SL higher than 1 can also choose to take part in the QA. In this case, there is an upward change of the manuring rules to 130 kg of organic nitrogen per hectare and per year on cropland and to 250 kg of organic nitrogen per hectare and per year on pastureland.

A new SL value is calculated for their farm on the basis of these rules. If this value is still higher than the unit, they must establish effluent transfer contracts in parallel to the latter in order to bring their SL below the unit.

3. On these QA farms, the implementation dynamics for good agricultural practices constitute a third implementation indicator for the Action Programme.

The farmer will benefit from the support of Nitrawal to optimise actions in favour of controlling nitrogenous flows, such as:

- the reduction of the annual pasturage duty;

- the protection of waterways (reduction of access to waterways for livestock, the installation of off-ground drinking troughs, etc.);
- integrated nitrogenous fertilisation;
- winter coverage for a significant percentage of the harvested land before 15 October;
- recourse to an efficient manuring method.

Each year, Nitrawal will compile an inventory of the good agricultural practices applied on each farm in the QA.

4. The systematic nitrogen balance constitutes the fourth implementation indicator for the Action Programme. It is implemented annually at farm and crop rotation level. The balance amount is constituted of the nitrogen losses in the air and the water and of storage in the organic soil matter. This amount will be compared with a theoretical amount calculated on the basis of optimal nitrogen effectiveness, while taking account of the crops and the type of livestock on the farm.

5. A fifth indicator is an indicator of the risk of nitrate lixiviation over all farmland. It is obtained by the combination of two indicators. These two indicators are calculated annually on each farm involved in the QA.
   a) On the one hand, a theoretical risk indicator is calculated for crop rotation. This indicator takes account of the part of the farm area which is used for high risk crops (e.g. potatoes and maize), medium risk crops (e.g. beet) and low risk crops (e.g. cereals with catch crop and hay-fields).
   b) A performance indicator for nitrogenous manure is also calculated using profile concentration measures for nitric nitrogen. Each year, the farmer carries out soil analyses on five of his parcels of land in order to determine the nitric nitrogen concentration profile (90 cm in depth in three layers of 30 cm).

The results of these analyses are compared with the reference values established annually per crop through the agricultural area survey (see Data interpretation).
In order to guarantee the quality of the measurement of the nitrogenous remainder, the two agronomic universities worked together with reference laboratory REQUASUD (Walloon Agricultural Research Center, B-5030 Gembloux, Belgium) to draft a sampling and soil analysis protocol (determination of the nitric nitrogen concentration) (Marcoen et al, 2003). The laboratories involved in these analyses must participate three times per year in a ring test organised by REQUASUD with the support of the DGA.

At the end of a 4-year commitment to the Quality Approach, Nitrawal develops an overview of the indicators and their development. On the basis of the latter, the DGRNE will consider the renewal of the Quality Approach for the farmer concerned.
In the case of a negative opinion, the farmer must adapt his farm or export surplus nitrogen so as to re-establish an SL value lower than the unit. This SL will be calculated using the basic rules (80/210 kg N ha^{-1} in vulnerable zones and 120/210 kg N ha^{-1} outside vulnerable zones).

6. The sixth indicator is an indicator of technical knowledge. It is the attendance frequency at the information and technical meetings organised regularly by Nitrawal and the FWA. In 2002 for instance, 133 meetings brought together 4200

farmers. A summary is made each year in order to measure the farmers' interest in the integrated management of nitrogen (Nitrawal asbl, 2003).

3 DISCUSSION

3.1 Data interpretation

The implementation of this Action Programme has just started, as the law (Decree from the Walloon Government concerning the sustainable management of nitrogen in agriculture) was promulgated in the Moniteur Belge on 29 November 2002. Consequently, little information is available and open to interpretation.

The aforementioned agricultural area survey is comprised of a number of representative points. The methods used to understand the nitrogen flows are concentrated on these sites and the references locally acquired can then be extrapolated to the agricultural regions.

Twenty-six farms were thus selected on the basis, among other things, of pedological criteria, in order to be representative of the regions to which they belong. They constitute the referential for the "agricultural area survey". Around 200 parcels of land were consequently chosen on these 26 farms. These farms benefit from supervision consisting in part in the generous provision of suitable manuring advice, the aim of which is to minimise nitrogenous residue as much as possible for the crop being grown.

The nitrogenous residue reference values are established on the basis of the measurements of nitric nitrogen concentration profiles developed three times each autumn (in October, November and December) on the parcels of land in the agricultural area survey.

Since the beginning of this year, lysimetric sinks have been installed on several parcels in the agricultural area survey. The objective is to establish a relationship between these nitrogenous residue reference values for the soil and the concentration of nitrate in the water gathered under the root zone.

Alongside this instrument, a model which was developed and validated within one vulnerable zone will soon be used and defined on these parcels.

3.2 Difficulties encountered

In addition to the production rules per animal category, legislation provides for the possibility of determining the quantities of effluent to be transferred between farms on the basis of the organic nitrogen quantity actually contained in the effluent. The determination of this quantity poses significant difficulties in practice. The results of the effluent analysis differ from one laboratory to another and make it difficult to determine the precise quantities of effluent to be transferred. Work on the harmonisation of the laboratories' analysis methods is under way, as is the finalisation of a method of estimating the losses based on the nitrogen (N) and phosphorous (P) excretion balances and the analysis of the effluent. P is a relatively immobile element that can be used as a reference to evaluate nitrogen losses. The comparison of the N:P ratio measured in the effluent and the N/P ratio expected on the basis of the excretion balances makes it possible to quantify the loss of nitrogen in the particular conditions of the farm concerned.

4 REFERENCES

Lambert R., Van Bol V., Maljean J.-F., Peeters A. (2000) Prop'eau-sable. Projet pilote pour la protection des eaux de la nappe des sables bruxelliens. Pilot project for the protection of the aquifer water of the Brusselian sand. Rapport final d'activités. Mars 1997 – mars 2001, 107 pp.

Marcoen J.M., Mohimont A-C, Vandenberghe C. (2003) Convention-cadre relative au Programme de Gestion Durable de l'Azote en agriculture wallonne – Rapport d'activités annuel intermédiaire 2002 de GRENeRA – FUSAGx, 84pp + annexes.

MRW – DGRNE et coll. (2000) Etat de l'Environnement Wallon 2000.

MRW - CSWAAA - (2000) Evolution de l'économie agricole et horticole de la Région wallonne : Volume 1.

MRW - CSWAAA - (2000) Evolution de l'économie agricole et horticole de la Région wallonne : Volume 2: tables and annexes.

Nitrawal asbl (2003). Convention-cadre relative au Programme de Gestion Durable de l'Azote en Agriculture wallonne. Framework convention on the Walloon Sustainable Management Programme for Nitrogen in Agriculture - Rapport annuel intermédiaire 2002.

Ministère des Classes Moyennes et de l'Agriculture (2001) Development of the agricultural and horticultural economy in 2000.

European Consilium – (1980). European Directive 80/778/CEE relating to the quality of water intended for human consumption (JO n° L229, 30/08/1980).

SEQ-EAU, French Water Agencies, (1999), Système d'évaluation de la qualité des cours d'eau, web site: www.rnde.tm.fr

Norme AFNOR NF T 90-354, (2000), Association française de Normalisation, Qualité de l'eau – Détermination de l'Indice Biologique Diatomées (IBD), 63p.

Coste, (1982) "Indice de polluosensibilité" (IPS), ed. CEMAGREF, France.

Dautrebande S., Dewez A., Guiot J., Hallet V., Monjoie A., Rouxhet F. (1996). Programme – Action Hesbaye. Rapport final 1993-1996. Ministry of the Walloon Region, DGRNE.