Report on the assessment of the water quality of the Meuse River basin based on data from the International Meuse Commission's Homogeneous Measurement Network (HMR)

(Period 2017-2019)

English not being one of the IMC's official languages, the English version of this report is not an official translation and is only provided to make this report more widely available.

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1. Introduction

The Meuse River basin district covers a little less than 35,000 km² spread over France, Luxembourg, Belgium, Germany and the Netherlands. Its population is approximately 9 million. The river itself is 905 km long and has an average flow of 350 m³/s at its mouth. It rises in France at Pouilly-en-Bassigny and flows into the North Sea at Haringvliet in the Netherlands. The upstream part of the river is characterised by the predominance of agricultural and forestry activities and a relatively low population density, in contrast to the downstream part.

Aware of the interest of the Meuse heritage and the importance of international coordination for its protection, the riparian states of the river decided in 1994, in Charleville-Mézières (France), to create the International Commission for the Protection of the Meuse (ICPM), which became the International Meuse Commission (IMC) in 2002 following the Ghent agreements. The French, Walloon, Flemish, Dutch, German and Luxembourg partners in charge of the management of aquatic environments meet to exchange on the major transnational issues concerning the Meuse and its tributaries, such as water quality and quantity, pollution, the impact of global changes and the ecological rehabilitation of the river and its tributaries.

Picture 1: Confluence of the Meuse and Sambre rivers in Namur (Source: Pixabay)

In order to carry out this task in a coordinated manner, the various delegations meet, among other things, in the "monitoring" working group, which, as early as 1998, jointly defined the structure of a homogeneous measurement network (HMR) for monitoring the quality of surface water in the Meuse basin at international level. This monitoring was initially limited to the 905 km of the main river before being extended to its main tributaries in 2011. While initially only some of the physico-chemical parameters were included in the HMR, a number of biological parameters were added later. The list of substances and parameters whose data are shared by the delegations is shown in table 1.

Group of parameters	Parameter	Group of parameters	Parameter
General parameters	Flow	**PAH**	Fluoranthene
	Water temperature		Benzo(b)fluoranthene
	Dissolved oxygen		Benzo(k)fluoranthene
	Oxygen saturation		Benzo(a)pyrene
	pH		Benzo[ghi]perylene
	Electrical conductivity at 20°C		Indeno(1,2,3-cd)-pyrene
	Suspended matters		Anthracene
	Chlorophyll-a	**Organic components**	Di(2-ethylhexyl)phthalate (DEHP)
Organic substances	Dissolved organic carbon		4/1-(para)-nonylphenol
Eutrophying substances	Total Phosphorus		Para-tert-octyl phenol
	Orthophosphates		Pentachlorophenol
	Total nitrogen		Tributyltin-oxide
	Ammonium		1,2-Dichloro-Ethane
	Nitrites	**PCB**	PCB 28
	Nitrates		PCB 52
Inorganic substances	Chlorides		PCB 101
	Sulphates		PCB 118
Heavy metals (dissolved fraction)	Mercury		PCB 138
	Nickel		PCB 153
	Zinc		PCB 180
	Copper	**Biology**	Diatoms
	Lead		Macroinvertebrates
	Cadmium		Macrophytes
	Cobalt		Fish
Pesticides	Simazine		
	Atrazine		
	Desethylatrazine		
	Diuron		
	Isoproturon		
	Alachlor		
	Chlorfenvinphos		
	Chlorpyrifos		

Table 1 : Parameters monitored in the IMC's homogeneous measurement network

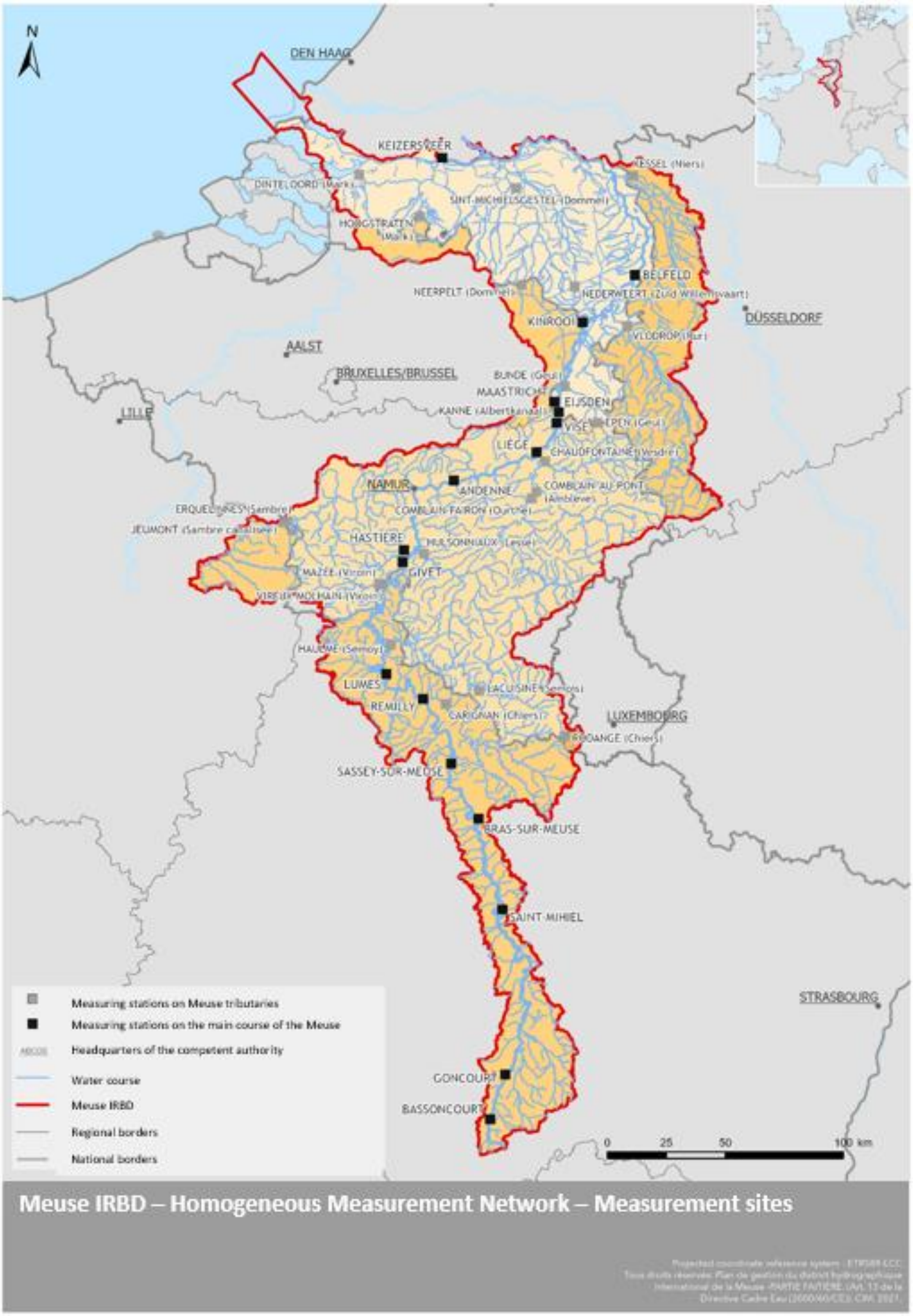
For the monitoring of physico-chemical substances in surface waters, the HMR relies on a total of 39 measurement sites (16 on the main course of the Meuse and 23 on its tributaries), 37 of which are also subject to biological monitoring. The location of the sites is shown on map 1. In practice, the delegations collect physico-chemical and biological data on their territory within the framework of their own monitoring programme resulting from European directives (Directives 2000/60/EC [1], 2008/105/EC [2] and 2013/39/EU [3]) and pool these results within the IMC for dissemination.

The purpose of this document is, 3 years later, to update the report published in 2018 and to present the new data collected during the period 2017-2019 in order to summarise the evolution of surface water quality in the Meuse basin.

When reading this report, it is useful to bear in mind that it is not part of the application of the Water Framework Directive (WFD) 2000/60/EC [1], which requires an assessment of surface water bodies. Although we use in this report data collected as well as certain standards or thresholds applied within the framework of the WFD, our aim will be to evaluate, at specific points, some parameters allowing the assessment of the quality of the watercourse and not to give a quality or a global state of a water body as provided for by this Directive. This report will, we hope, provide a particular and complementary perspective on the results of the monitoring, focusing in particular on:

- ✓ Elements of comparison from upstream to downstream of the river basin,
- ✓ Evolution of monitored elements over time,
- ✓ Specific substances of particular interest to the river basin,
- ✓ Some aspects of biological monitoring.

Picture 2: The Albert Canal from the lock at Lanaye



Map 1: Location of the HMR sites

2. Physico-chemical quality

2.1. Macropollutants

Macro-pollutants are substances that occur naturally in watercourses and are non-toxic in low concentrations. It is only at high concentrations in the range of one milligram per litre - usually as a result of human activities - that they harm aquatic plants and animals. These include nutrients such as nitrogen and phosphorus, but also chloride and organic pollutants. Under this section, we will also deal with physico-chemical parameters such as pH, oxygen concentration and conductivity.

a) Organic matters

Surface waters are complex ecosystems capable of self-purification, allowing them to recycle organic matter (especially lipids, carbohydrates, proteins; essentially carbon-based molecules) produced by biological activity. This self-purification is mainly based on the presence of oxygen (O2) which ensures, through multiple biochemical reactions, the transformation of organic matter into carbon dioxide (CO2). This degradation is carried out by aerobic micro-organisms that use biodegradable organic compounds as their main source of energy.

In their natural state, surface waters reach a state of ecological equilibrium, but this can be profoundly disrupted when anthropogenic inputs of nutrients and exogenous organic matter exceed the assimilation and self-purification capacities of the environment.

Monitoring the amount of dissolved oxygen in water is a good way to assess their contamination by organic matter, whether natural or man-made. It is also one of the essential factors for the life of flora and fauna.

The dissolved oxygen concentration in the water depends on several factors, including the microbiological activities of degradation of the above-mentioned organic matter and other biochemical reactions, exchanges with the air, photosynthesis and the temperature of the water. It can vary very rapidly, particularly over a 24-hour period, depending on the alternation of day and night and biological activity.

In recent years, the evolution of the dissolved oxygen parameter in the Meuse River basin has been positive overall. Not only have the regions that were little affected by organic pollution at the beginning of the 2000s (such as Saint-Mihiel in Figure 1) remained of good quality, but also the regions that in the past had dissolved oxygen deficits that were sometimes quite significant (such as Visé) have gradually improved, with the deficits becoming rarer since 2006. These improvements in the oxygen levels of the watercourses are the result of the efforts made by the various States and Regions of the International Meuse River Basin District. These efforts concern all sources of pollution in terms of organic matter in watercourses and, more particularly, the treatment of urban wastewater in application of European Directive 91/271 [5] on the treatment of urban waste water, but also the reduction of industrial and agricultural organic inputs.

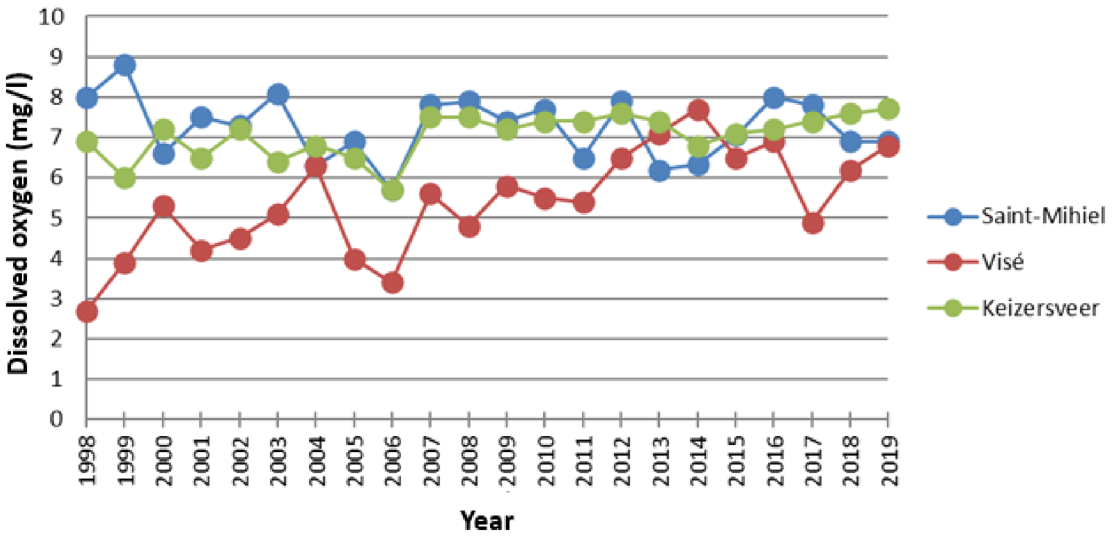


Figure 1: Temporal evolution of the minimum annual dissolved oxygen concentration measured at three sites in the main course of the Meuse

On the basis of the data exchanged in the HMR, this positive observation can be extended to the entire Meuse basin. Some particularly important improvements can be highlighted, for example on the Albert Canal at Kanne or the Vesdre at Chaudfontaine (Figure 2).

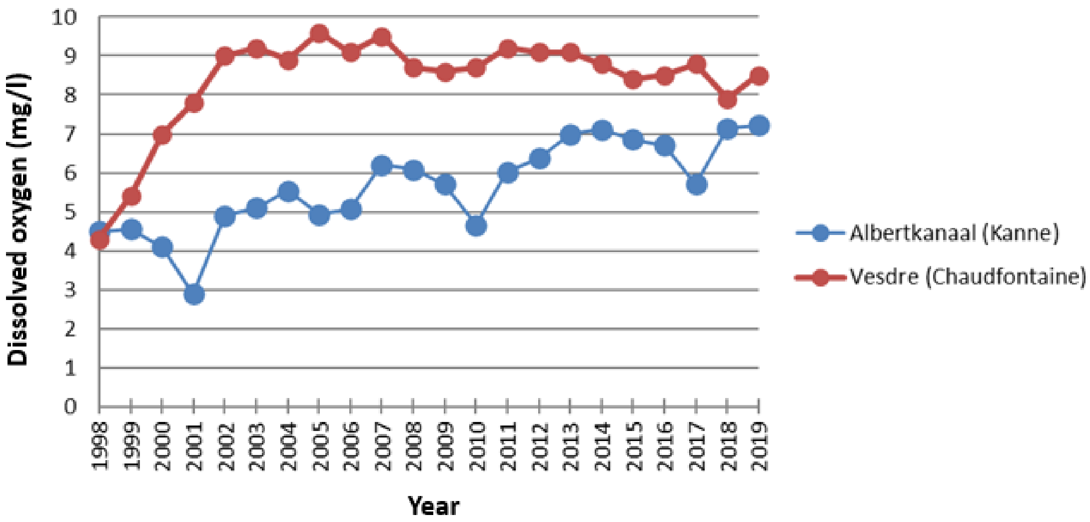


Figure 2: Temporal evolution of the minimum annual dissolved oxygen concentration measured at sites on the Albert Canal and the Vesdre

b) Nutrients

In surface waters, nitrates and phosphates are mineral nutrients produced naturally by the degradation of organic matter and are essential, at low concentrations, for the natural functioning of our rivers. However, when they are present in excessive quantities, they disturb the ecosystem by causing excessive development of microorganisms and aquatic plants. This phenomenon is called eutrophication. In addition to this eutrophication, the pH and dissolved oxygen concentrations produced by photosynthesis increase during the day and decrease at night (oxygen production stops and is consumed by organisms for respiration). The differences in dissolved oxygen concentrations in water are sometimes so significant that they become fatal for certain fish populations.

The longitudinal evolution of total nitrogen and total phosphorus concentrations is presented in figures 3 and 4.

If we look at the evolution of total nitrogen from the source of the Meuse to its mouth, we see that the concentrations differ sharply upstream and downstream of the Belgian-Dutch border. While concentrations upstream of Visé are relatively stable between 3 and 3.5 mg nitrogen per litre, they rise to around 4 mg nitrogen per litre downstream of Eijsden.

In the current state of knowledge, no satisfactory explanation can be given for this increase with certainty. Indeed, no nitrogen input from a specific discharge or from a heavily polluted tributary is known in this section of the Meuse. On the other hand, the question of a difference in the analysis methods used is a potential possibility that should be investigated in the future, especially as such an increase at the border is observed in other river basin districts, which reinforces the hypothesis of methodological and analytical artefacts.

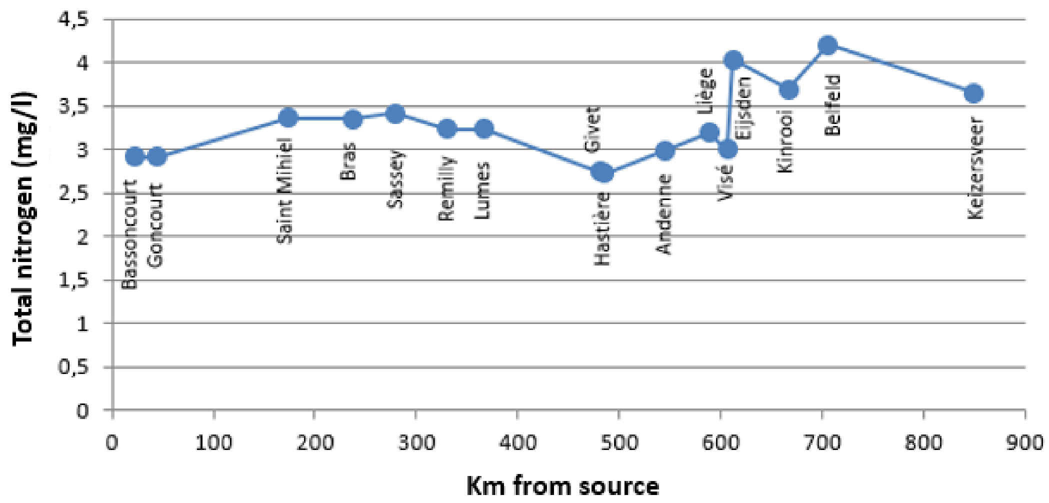


Figure 3: Longitudinal evolution of the average concentration of total nitrogen in the Meuse River from 2017 to 2019

Regarding total phosphorus, the concentrations upstream of the basin are relatively high compared to what can be observed on the rest of the French course of the Meuse. The combination of intense agricultural pressure (mainly livestock farming) and low flows in this section largely explains this observation.

For this parameter, an increase in the measured concentrations between Andenne and Liège can also be observed. This could be partly explained by the discharges of an industry active in phosphate chemistry located upstream of Liège.

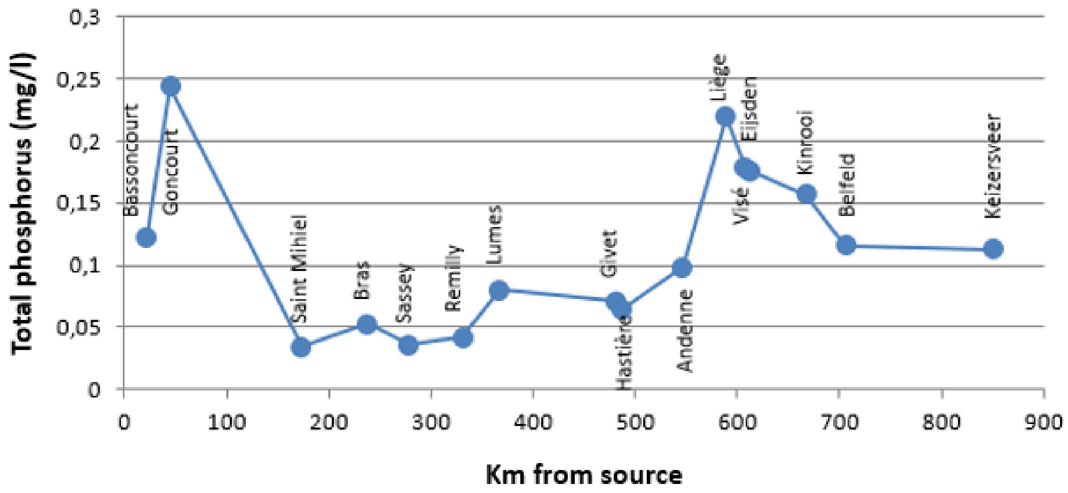


Figure 4: Longitudinal evolution of the average total phosphorus concentration from 2017 to 2019 in the Meuse River

Concentrations of eutrophying substances, such as nitrogen and phosphorus, are still a major challenge for the quality of the Meuse and the North Sea. Overall, we observe a decreasing temporal trend for these substances since 1998 in the main course of the Meuse (Figures 5 and 6) and its main tributaries such as the Amblève and Semoy (Figures 7 and 8). However, in recent years, the concentrations of nutrients seem to have stabilised or even increased in the case of nitrogen at certain measurement sites.

Indeed, for measurement sites located in areas where there is significant agricultural pressure (the Meuse at Saint-Mihiel), a more or less significant increase in total nitrogen concentrations can be observed.

These increases in average concentration are linked to an increase in peaks generally observed in early winter (November to January). These peaks result from the leaching of surplus agricultural nitrogen. This fairly usual phenomenon has been greatly accentuated in recent years by the hot, dry and longer summers we have experienced, which may have reduced agricultural production yields. The inputs were not sufficiently adapted, plant growth and therefore nitrogen consumption were lower, which led to an increase in surpluses. As we will see later in this report, it is mainly the share of nitrate in total nitrogen that has increased, while ammonium has remained relatively stable.

Furthermore, as we have just seen, total nitrogen and total phosphorus concentrations remain relatively high in the Lower Meuse. Efforts will have to be maintained in the coming years to ensure that the improvements registered continue. Measures in the field of agriculture (crops and livestock) or in the field of water purification are potentially effective in improving the state of aquatic ecosystems (see chapter 3.1.).

Excessive nutrient concentrations can lead to eutrophication in the North Sea and coastal waters. In order to achieve the environmental objectives of the WFD and the EU Marine Directive, it is important that the concentrations of nutrients, and in particular nitrogen, in the rivers of the Meuse catchment area continue to decrease.

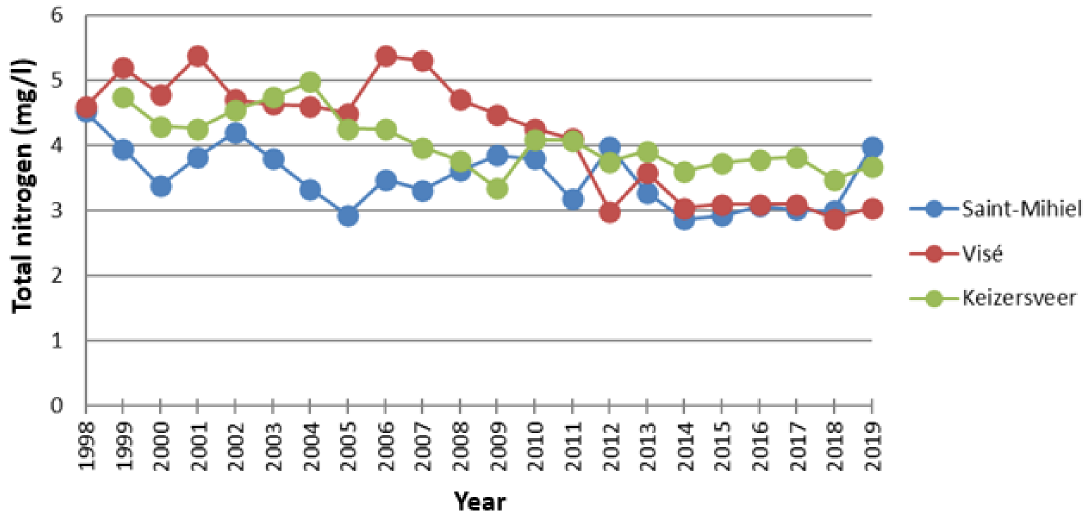


Figure 5: Temporal evolution of the annual average concentration of total nitrogen at 3 sites in the Meuse River

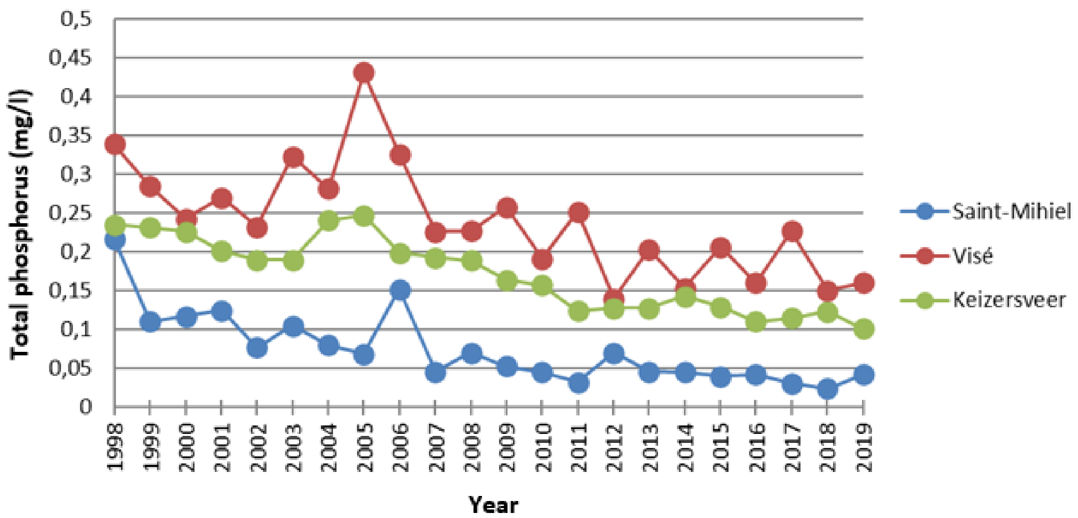


Figure 6: Temporal evolution of the annual average concentration of total phosphorus in 3 sites of the Meuse River

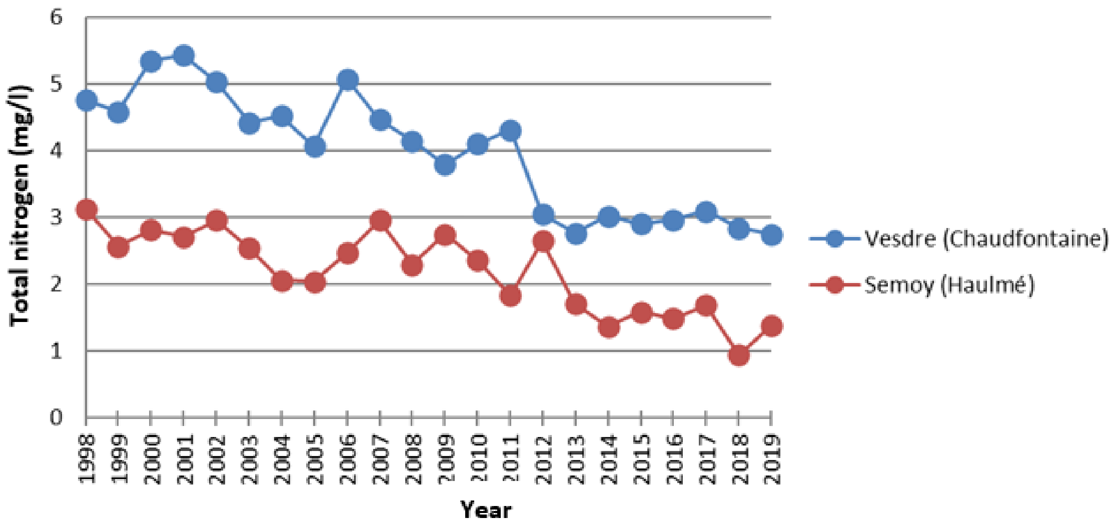


Figure 7: Temporal evolution of the annual average concentration of total nitrogen in sites located on the Vesdre and Semoy rivers

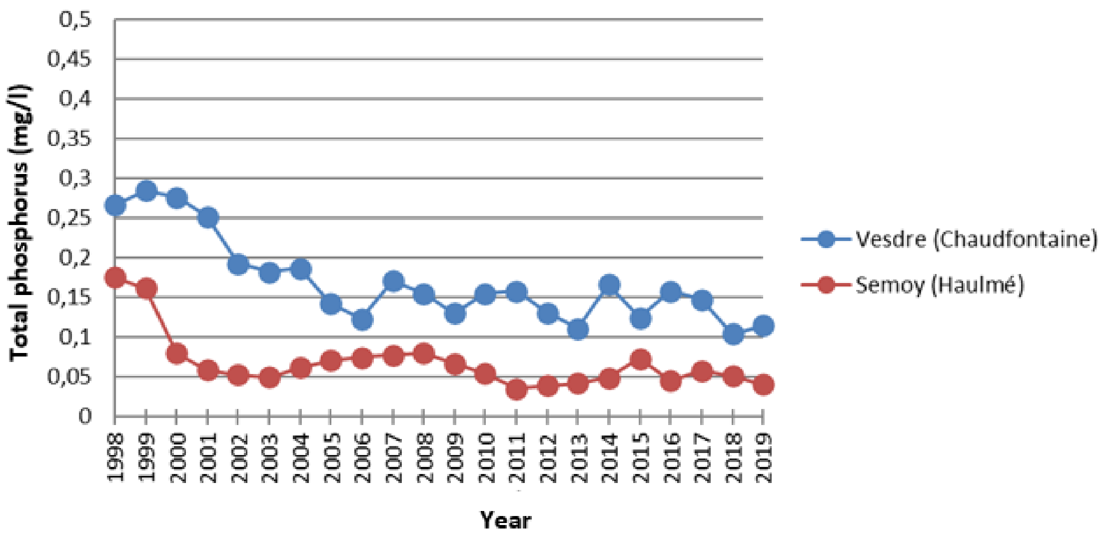


Figure 8: Temporal evolution of the annual average concentration of total phosphorus in sites located on the Vesdre and Semoy rivers

This improvement in the nutrient situation in the Meuse basin also seems to be reflected in the average annual chlorophyll a concentrations measured in the main course of the Meuse (Figure 9). These concentrations decrease significantly over time along the entire length of the Meuse. A similar observation can be made for all the tributaries of the Meuse for which data are exchanged within the HMR. Chlorophyll a is the main photosynthetic pigment present in plants. This variable, measured in water, makes it possible to estimate the biomass of planktonic algae (phytoplankton), one of the markers of eutrophication.

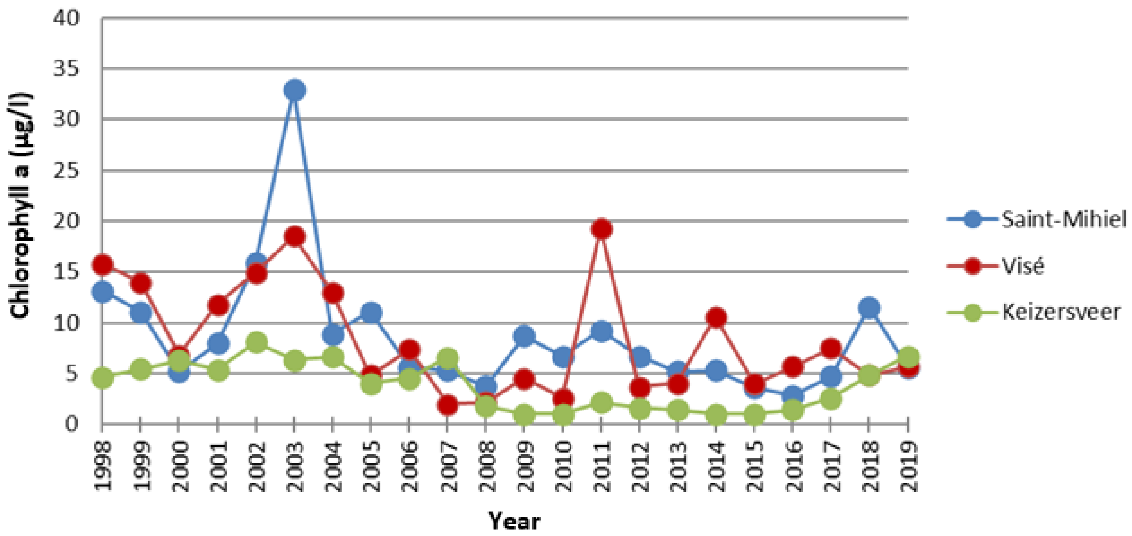


Figure 9: Temporal evolution of the annual average concentration of Chlorophyll a in 3 sites of the Meuse River

This decrease may be the result of the decrease in nutrient concentrations but could also, at least in the Meuse, be the result of the arrival of new species of filter-feeding bivalve molluscs (*Dreissena rostriformis bugensis* and *Corbicula spp*.) in the early 1990s, which consume phytoplankton. We will come back to this point in chapter 3.1 on phytoplankton.

c) Nitrates

Nitrates in surface waters come mainly from agricultural activities. Nitrates can lead to excessive algal growth, particularly in marine waters where they are concentrated. A European directive is specifically focused on them (Directive 91/676/CEE [4]).

The average nitrate concentrations measured on the main course of the Meuse have remained stable overall since 1998. A slight improvement can be seen in the downstream section of the Meuse, as can be seen in figures 10 and 11. An increase in the maximum and average annual values measured in recent years can also be observed at the Meuse measurement site in Saint-Mihiel for the reasons explained above (chapter 2.1.b).

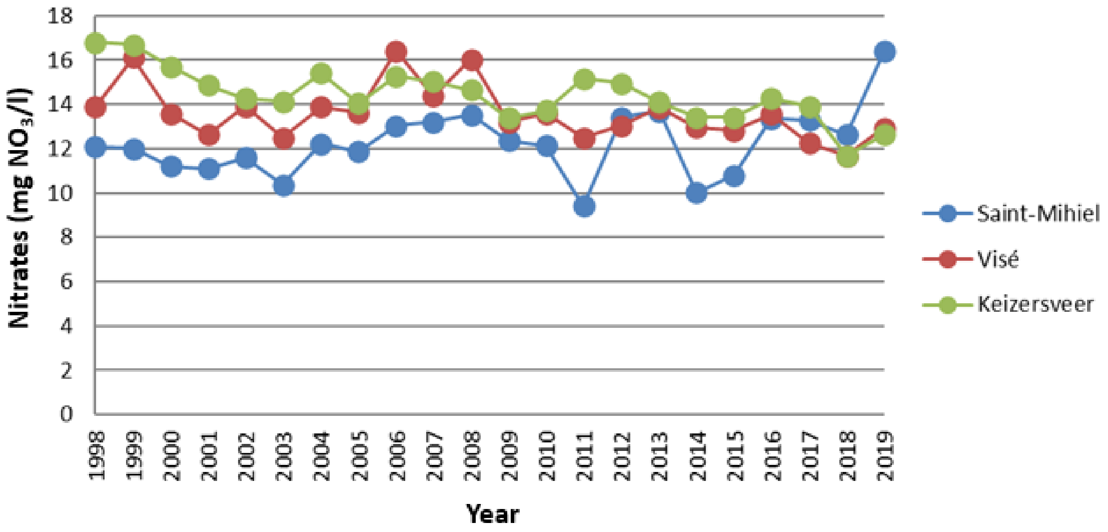


Figure 10: Temporal evolution of the annual average nitrate concentration at 3 sites in the Meuse River

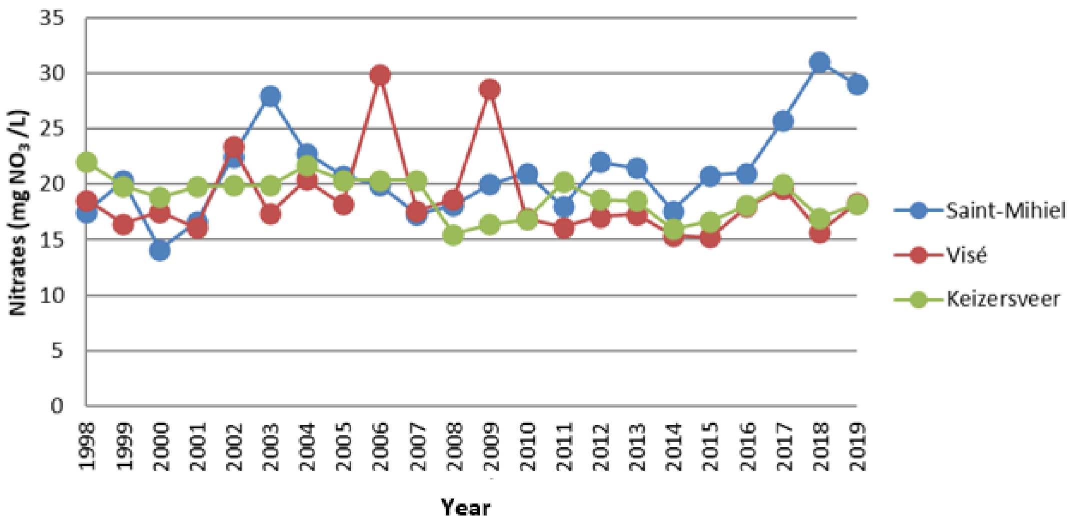


Figure 11: Temporal evolution of the maximum annual nitrate concentration in 3 sites of the Meuse River

The situation is similar throughout the basin. However, there are some much more positive developments in some rivers with higher nitrate concentrations in the early 2000s. Examples are the Mark and the Dommel (figure 12).

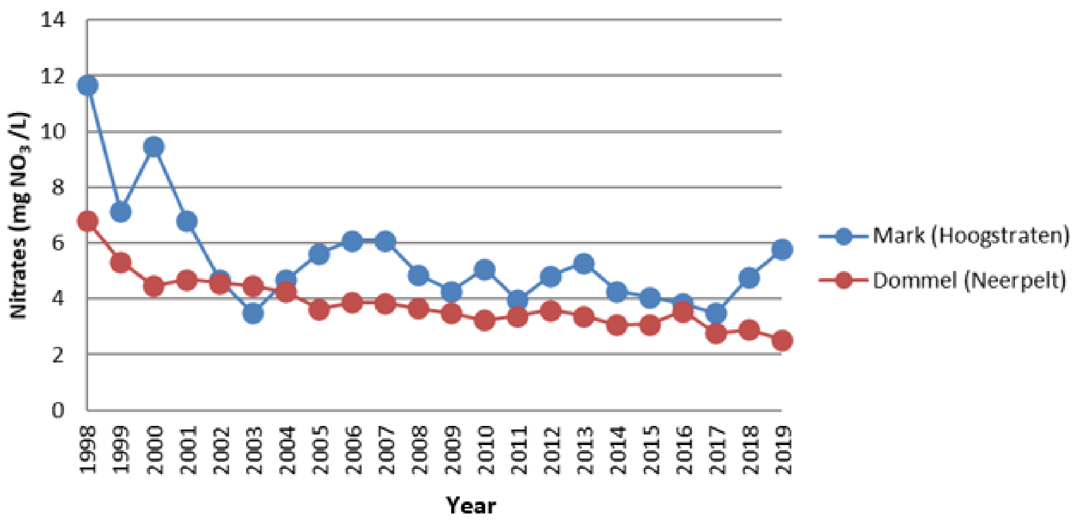


Figure 12: Temporal evolution of the maximum annual nitrate concentration at sites on the Mark and the Dommel

At present, there are no harmonised standards at regional or European level that would allow us to carry out a common environmental assessment of this parameter. However, if we refer to the "nitrates" directive [4], a value of 50 mg NO_3/l is defined as the limit value not to be exceeded in surface water intended for drinking water supply. It appears that the entire Meuse River basin and its tributaries monitored by the HMR have nitrate concentrations that are generally well below this standard (map 2).

It is nevertheless true that occasional problems linked to nitrates may exist in certain more agricultural areas of the Meuse basin. On this issue, it should be mentioned that two values above 50 mg/L were observed in Bassoncourt and Goncourt (respectively 60 and 51 mg/L on 10/12/2018). However, the analysis of the data for the period 2017-2019 is based on the 90 percentiles over 36 months, so these maximum values are not taken into account in Map 2. The longer-term trend is under observation and must be analysed on the basis of more recent data.

Map 2 : Comparison of the maximum nitrate concentrations recorded in the HMR during the period 2017-2019 with the "Nitrates Directive" standard

2.2. Temperature

The temperature of the Meuse is continuously monitored at four measurement sites located in Wallonia and the Netherlands. This monitoring will, among other things, make it possible to highlight the consequences of climate change on this parameter. A large amount of data is required to be able to observe a trend in the rise or fall of the temperatures measured. Since the first continuous records date back to 1999 for the Walloon stations and 2010 for the Dutch stations, it was decided to draw up a specific report on the subject after a minimum of 20 years of measurements at at least one site.

2.3. Micropollutants

In contrast to macropollutants, micropollutants are substances that are present in water in concentrations of the order of micrograms or nanograms per litre and can be toxic even at low concentrations. This term covers a wide range of substances, from metals to pesticides and a whole series of natural or anthropogenic organic compounds.

With the exception of copper, zinc, cobalt, desethylatrazine and PCBs, the micropollutants monitored in the HMR are all part of Annex X of the WFD, whose list of priority and dangerous priority substances was defined by Directive 2008/105/EC, known as the EQS Directive (Environmental Quality Standards) [2] and updated by Directive 2013/39/EU [3]. As a result, European standards exist for a common assessment of surface water contamination throughout the Meuse basin.

On the basis of these European standards, we will assess the current situation for the various micropollutants listed in the HMR in the following paragraphs, with particular attention to a group of substances known as ubiquitous PBT substances (see box*).

** What is a ubiquitous PBT substance*

In 2013, the European Commission adopted a new Directive, Directive 2013/39/EU [3], to amend the WFD, in particular its Annex X. In addition to modifying the list of priority substances and the environmental quality standards, this directive introduced a new concept of « ubiquitous persistent, bioaccumulative, toxic and substances» (ubiquitous PBTs). According to the Directive, these are substances that « can be found for decades in the aquatic environment at levels posing a significant risk, even if extensive measures to reduce or eliminate emissions of such substances have already been taken. Some are also capable of long-range transport and are largely ubiquitous in the environment. »

A list of 8 groups of ubiquitous PBT substances has been established: brominated diphenylethers, mercury, Polyaromatic hydrocarbons (PAH), Tributyltin compounds, perfluorooctane sulfonic acid (PFOS), dioxins, hexabromocyclododecanes and heptachlor. Three of these are monitored at the HMR level: mercury, PAHs and tributyltin cation.

a) Metals

Heavy metals are naturally occurring substances which, when present in excess, can be toxic to living organisms. Anthropogenic sources of heavy metals are diverse and their importance varies across the basin. As noted in previous triennial reports, progress has been made in recent years to prevent pollution by this type of compound. However, some rivers still have concentrations of certain metals in excess of authorised standards.

This is the case for dissolved cadmium, which has values above the European standards [3] upstream of one of the tributaries of the Meuse, the Dommel at Neerpelt (map 3). The origin of these high concentrations is partly linked to industrial discharges from a zinc smelter located in the basin of this river. It should be noted that a significant decrease in dissolved cadmium concentrations measured at this site can be observed compared to the values recorded before 2006 (Figure 13). This improvement can be at least partially attributed to the efforts made by the company involved to minimise the impact of its discharges on the watercourse.

For the sake of completeness, two exceptional values for dissolved cadmium measured on the Meuse at Eijsden (6.8 µg/l on 6/3/2018) and Kinrooi (2.71 µg/l on 7/3/2018) following an event of unknown origin should be mentioned.

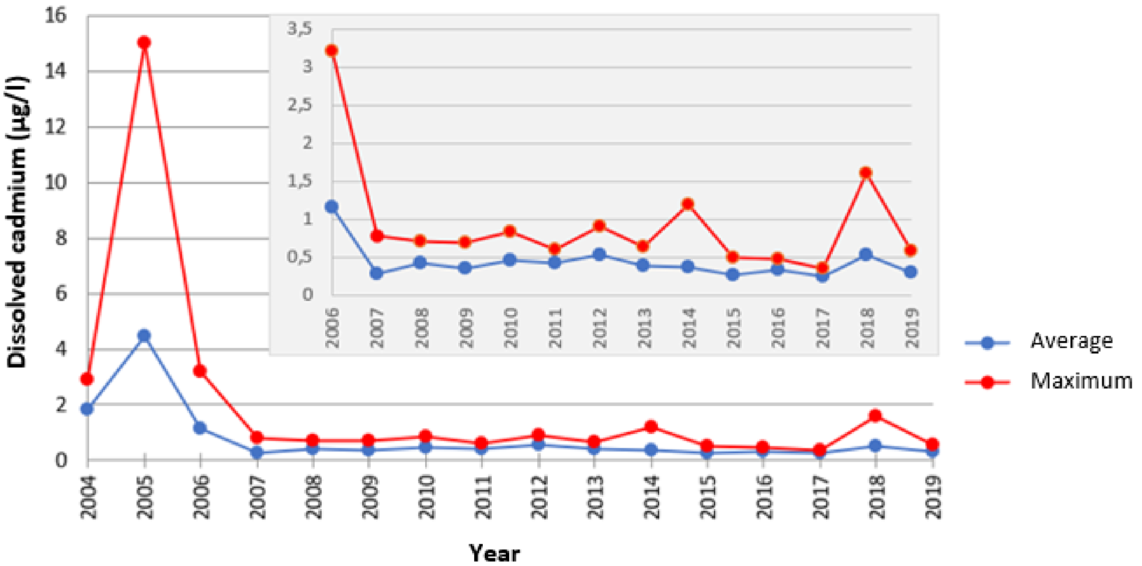
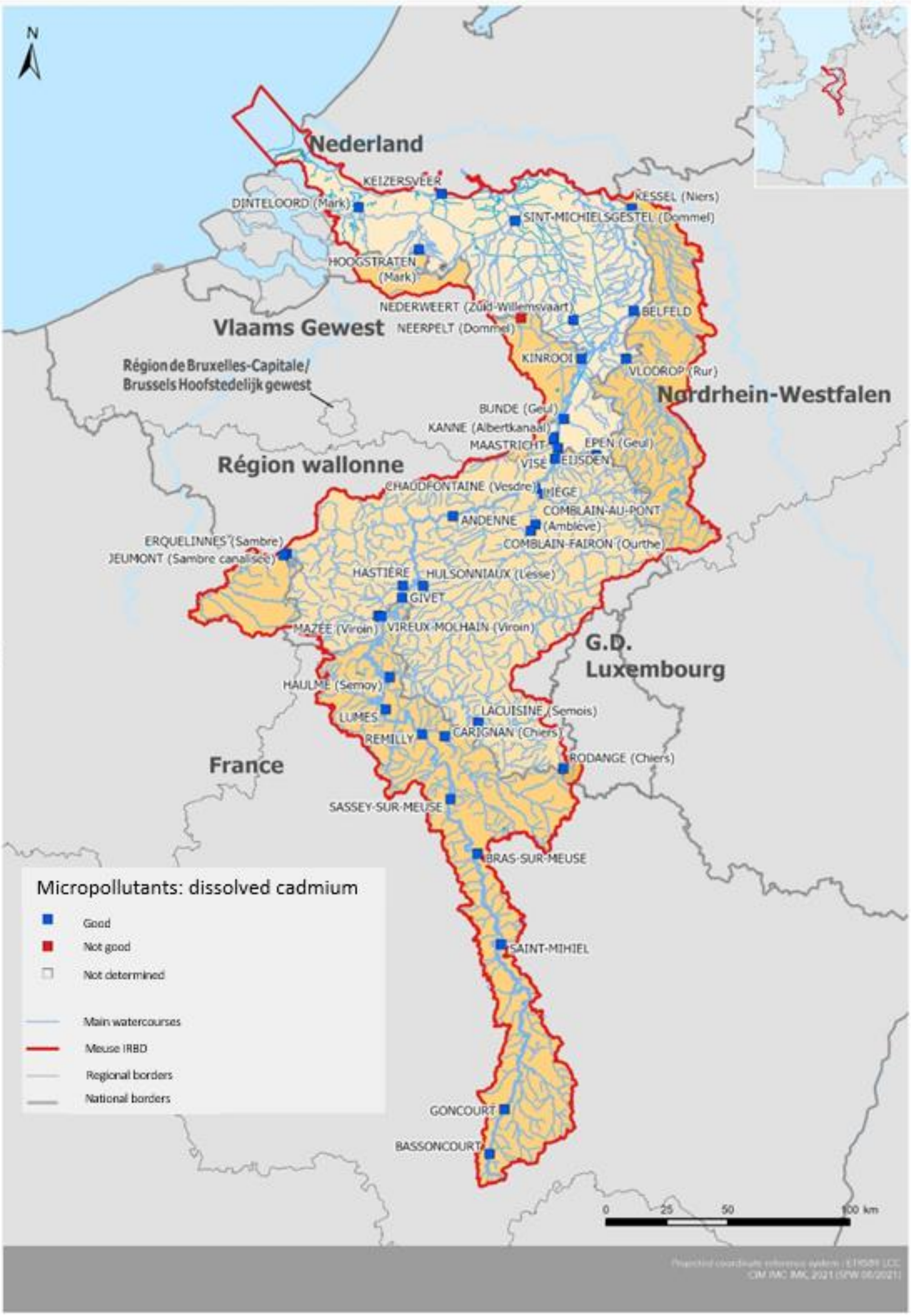


Figure 13: Temporal evolution of average and maximum annual dissolved cadmium concentrations at a site on the Dommel in Neerpelt



Map 3: Concordance with the environmental quality standard of the annual average concentration of dissolved cadmium in water at all HMR sites for the period 2017-2019

The case of dissolved mercury in water is quite similar. Indeed, the vast majority of measurements carried out in water are below the limit of quantification but, occasionally, mercury can be measured at values exceeding the EQS applicable to surface water. This was the case, for example, in 2015 in Givet where this compound was exceptionally measured at a value of 0.42 µg/l. However, it should be noted that Directive 2013/39 [3] now recommends measurements on living aquatic organisms (fish and molluscs, collectively referred to as "biota") and sets a very restrictive EQS. As a result, the measurements carried out in the tissues of aquatic organisms by the States/Regions as part of their own monitoring programme seem to show widespread contamination of organisms by mercury.

In contrast, dissolved nickel and lead, two other heavy metals listed as priority substances under the WFD, have not exceeded their EQS since 2008 for the entire HMR. It should be noted that in the 2013 revision of the EQS Directive [2], the standards for these compounds were lowered and a new concept of bioavailability of metals was introduced. In the future, the consequences of these changes on the assessment of nickel and lead will have to be analysed.

There are no common standards for copper, zinc and cobalt across all delegations. However, national or regional standards exist for these metals for the whole or part of the basin. These standards may vary from one State or Region to another depending on the uses and references taken into account for these compounds.

For example, all delegations have defined a standard for copper in their legislation. Although these standards are different, the analysis of copper measurements in the Meuse basin shows that this parameter never exceeds the standard applied to it locally. On this basis, we can conclude that the copper concentrations found in the watercourses of the international Meuse district are no longer problematic.

Zinc is also assigned a standard by all IMC delegations. Unlike copper, this standard is regularly exceeded and work remains to be done on this parameter.

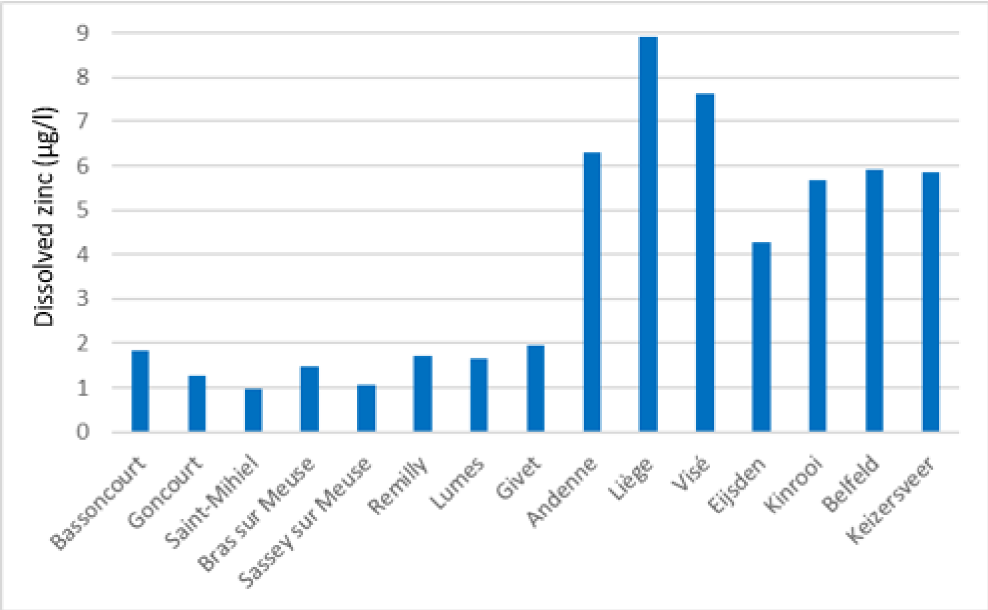


Figure 14: Evolution of the average concentration of dissolved zinc in the Meuse River over the period 2017-2019

(N.B.: A value below the limit of quantification (LOQ) was measured at the Hastière station (LOQ = 5µg/l), which justifies it's not being represented on this graph)

The case of cobalt is slightly more complicated to analyse as there are only standards for dissolved cobalt in the Netherlands (AA-EQS = 0.2 µg/l and MAC-EQS = 1.36 µg/l) and in Flanders (AA-EQS = 0.5 µg/l). Within the HMR, cobalt measurements have also been pooled and coordinated across the basin since 2016. In the absence of common standards, it is currently impossible to assess the impact on all the rivers of the Meuse basin. However, the data in our possession allow us to visualise the evolution of dissolved cobalt concentrations in the Meuse from upstream to downstream. As can be seen in figure 15, dissolved cobalt concentrations remain relatively low in the main course of the Meuse. In contrast, some tributaries such as the Dommel and the Mark have much higher average concentration values over the period 2017-2019 (5.59 µg/l in Neerpelt and 2.5 µg/l in Hoogstraten respectively).

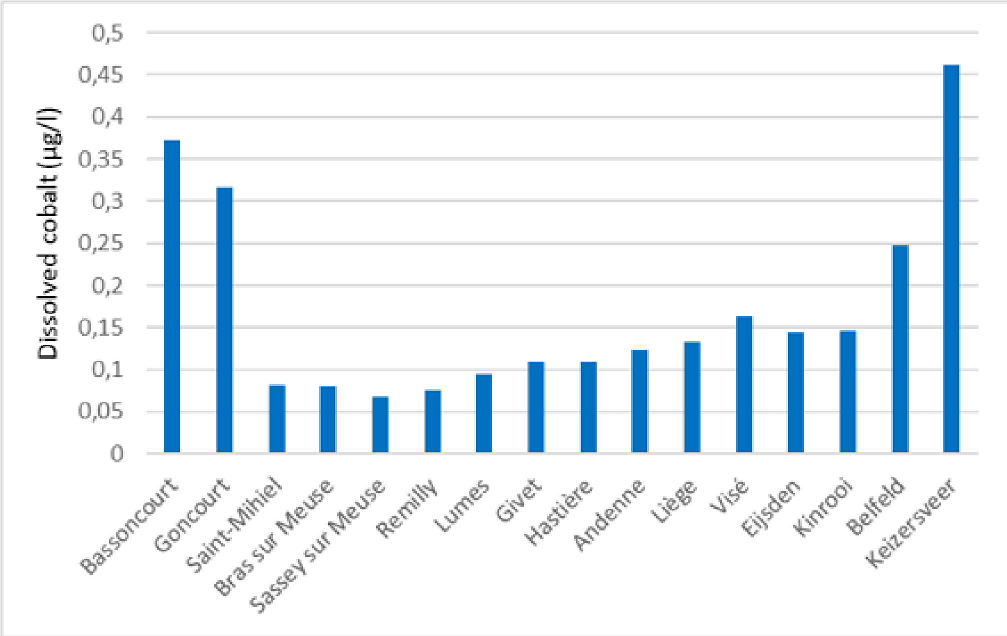


Figure 15: Evolution of the average concentration of dissolved cobalt in the Meuse River over the period 2017-2019

b) <u>Pesticides</u>

Many of the pesticides listed in Directive 2013/39/EU [3] are also monitored in the HMR. Generally speaking, none of these pose a global problem for the entire international river basin district, which seems quite logical given that for all the pesticides monitored in the homogeneous monitoring network, bans on their use have now been issued at the European level (for some for more than 10 years, for others more recently). Most of the measurements carried out during the 2017-2019 period are also below the quality standards or even the quantification or detection limits. However, some pesticides monitored in the HMR may exceed environmental quality standards more or less regularly.

To illustrate this, we can look at the examples of diuron and isoproturon, two substances defined as priorities by the EQS Directive [2].

Diuron, a pesticide that has been banned for many years, has seen its concentration in surface water gradually decrease to a situation where it is rarely quantified in samples taken (Figure 16).

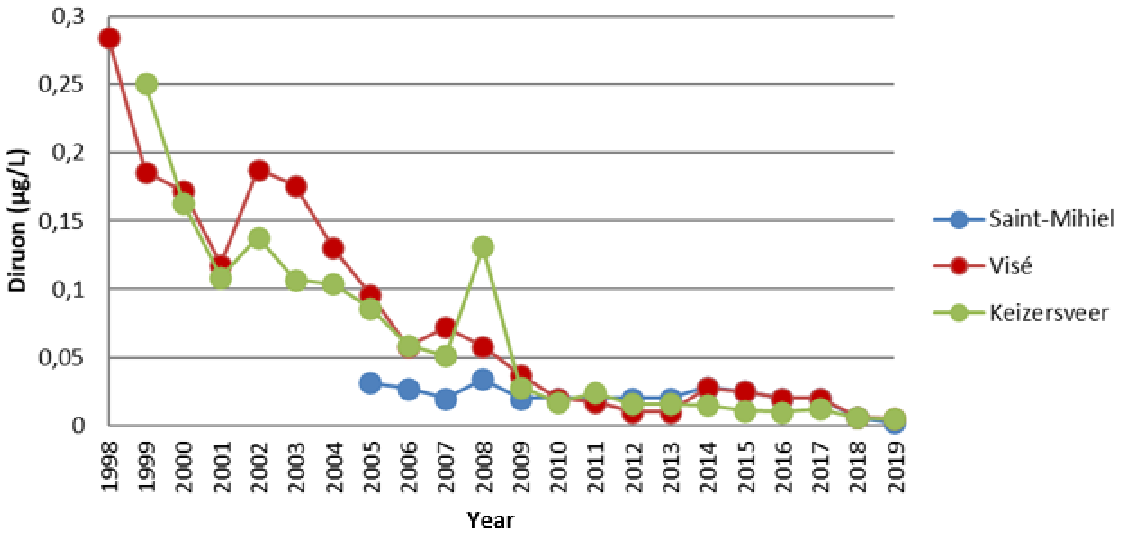


Figure 16 : Evolution of the annual average concentration of diuron at 3 sites in the main course of the Meuse

Under the current operating conditions of the HMR (monthly samples), maximum water concentrations of isoproturon, an herbicide with a long history of agricultural use, exceed the EQS [3] at only 1 of the 38 HMR monitoring sites in the period 2017-2019, namely the Geer in Maastricht. However, this pesticide is known to show large and very short-lived peaks during rainy autumn events (usually in October and November) and, to a lesser extent, in spring. A monthly sampling rhythm can easily miss such an event. The use of isoproturon was banned in 2017 by the European Commission.

It is important to bear in mind that the HMR only gives a partial picture of the pesticide situation in the Meuse basin. Indeed, we have to remember that its primary objective is to give an overall picture of the quality of the international district and not to identify local sources of input. Moreover, it only monitors some of the many active substances present in pesticides and at a monthly frequency. Other pesticides that are not monitored in the HMR may pose problems, either in terms of the quality of watercourses or for specific uses of the water in the Meuse. On this point, we can, for example, quote the most recent annual report of RIWA-Meuse[1].

Pollution by new substances is likely, in the future, to lead to scientific and legislative developments that could justify adaptations of future HMR monitoring programmes.

[1] RIWA-Meuse is an international association of Belgian and Dutch drinking water companies that use the water of the Meuse as a source for the production of drinking water. RIWA Annual Report 2019 The Meuse, 7 September 2020 (https://www.riwa-maas.org/en/riwa-maas-3/)

c) Polycyclic aromatic hydrocarbons (PAH)

Several PAHs are monitored in the HMR: anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene and indeno(1,2,3-cd)-pyrene. All of these substances are defined as being priorities by the EQS Directive [2] and therefore benefit from environmental quality standards applicable at European level. As for some metals, these standards have been modified by Directive 2013/39/EU [3] which also defined benzo(a)pyrene as a "marker" for the group of priority substances n°28 (Table 2). Therefore, the monitoring of this compound is sufficient to allow the assessment of environmental contamination by this group of substances.

Polycyclic Aromatic Hydrocarbons (PAHs) are molecules consisting of carbon and hydrogen atoms, with a structure that includes at least two aromatic rings.

There is no limit to the number of PAHs that can exist.

In the past, PAHs were of natural pyrolytic origin (e.g. forest fires, grassland fires, volcanic eruptions).

Today, PAH inputs are mainly of anthropogenic pyrolytic origin (coal, oil and natural gas combustion) and also come from the discharges of certain industrial branches. The PAHs produced in this way contaminate our waterways mainly in the form of atmospheric fallout, sometimes at a great distance from their place of emission.

They constitute a group of organic pollutants, most of which are considered as ubiquitous PBTs by the European Commission.

Nr.	Name of the substance	AA-EQS (µg/l)	MAC-EQS (µg/l)
2	Anthracene	0,1	0,1
15	Fluoranthene	0,0063	0,12
28	Benzo(a)pyrene	$1{,}7 \times 10^{-4}$	0,27
	Benzo(b)fluoranthene	/	0,017
	Benzo(k)fluoranthene	/	0,017
	Benzo(g,h,i)perylene	/	$8{,}2 \times 10^{-4}$
	Indeno(1,2,3-cd)pyrene	/	/

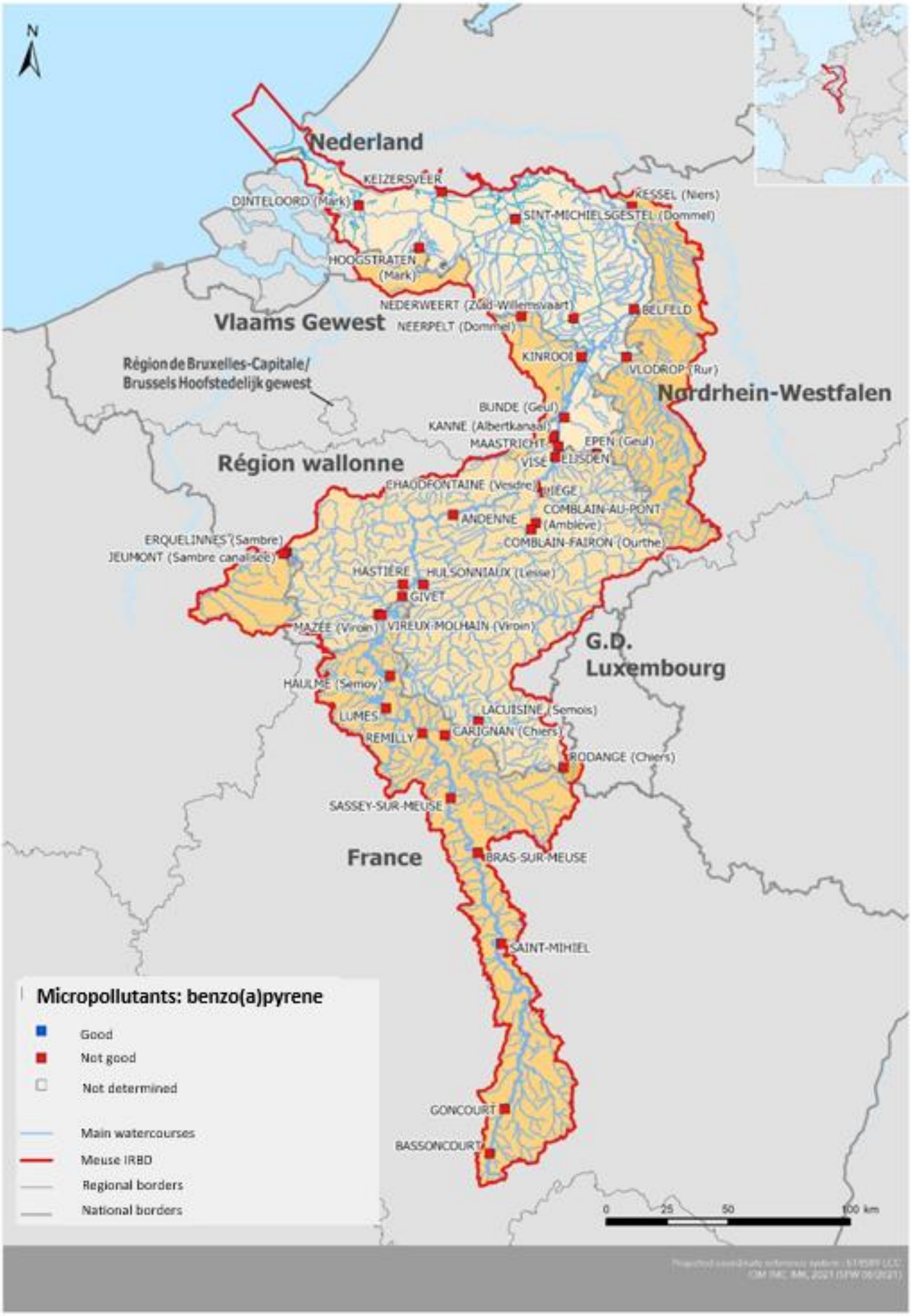
Table 2: Annual average environmental quality standards for (AA-EQS) and maximum acceptable concentration (MAC-EQS) in inland surface waters defined by the Directive 2013/39/UE [3]

PAHs are highly toxic, even in low concentrations, and are present in all environmental compartments. Thus, all of the HMR sites where these compounds are monitored had concentrations above the EQS for at least one of the monitored PAHs over the 2017-2019 period. This pollution is found both in the main course of the Meuse and in its tributaries. Map 4 illustrates this situation by showing the exceedances recorded over the period 2017-2019 for the average standard for benzo(a)pyrene.

However, this observation must be put into perspective by the fact that the standards set by the European Commission for the water compartment have been set at a relatively low level because of the high toxicity of PAHs. An analysis of PAH concentrations in living organisms and their comparison with the associated standards would certainly give a more contrasted picture of the problem.

It should also be noted that this situation is not unique to the Meuse basin. Indeed, the water bodies of the riparian river basins, such as the Scheldt, Mosel-Saar or Rhine basins, are facing the same situation.

It is also interesting to note that this problem goes far beyond the framework of water management since the main origin of these compounds is, as mentioned in the box, the combustion of organic matter and fossil fuels. This means that atmospheric deposition of PAHs, sometimes emitted from great distances, is the major source of PAH input to watercourses.



Map 4: Concordance with the EQS for the annual average concentration of benzo(a)pyrene in water at all HMR sites for the period 2017-2019

3. Biological quality

3.1. Phytoplankton

The phytoplankton of the Meuse has been the subject of numerous studies since the end of the last century. The phytoplankton community, which changes with the season depending on the flow rate and turbidity, is dominated by diatoms and green algae, with a phytoplankton bloom generally observed in the spring, consisting mainly of diatoms of the genus *Stephanodiscus*.

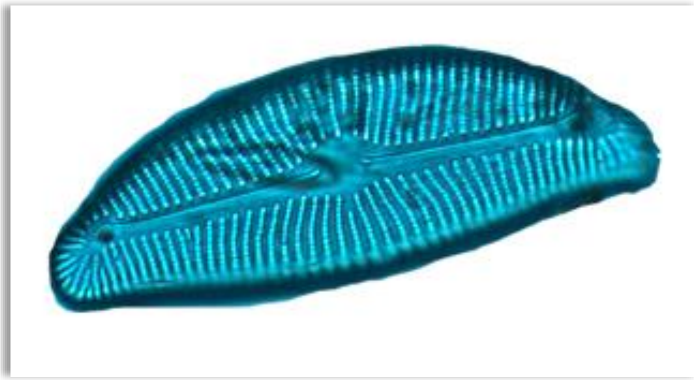
In recent years, a major decrease in the amount of phytoplankton and the chlorophyll a indicator has been observed in the Meuse, particularly in the Walloon Meuse (see Fig. 9), which could be due to the invasion of the Meuse by exotic benthic filter-feeding molluscs such as *Corbicula* spp. Although eutrophying loads are decreasing in the Meuse, the nutrient concentrations observed remain above the minimum limits necessary for phytoplankton development. As no other factor seems to be able to explain the phenomenon observed, it would therefore be the arrival of new filter-feeding molluscs and the development of their populations that would explain this strong reduction in phytoplankton biomass, improving the transparency of the water and thus giving the illusion of better water quality [4]. This reduction in phytoplankton has a cascading effect on other trophic levels, with poor development of zooplankton that feed the fry of many species of mosan fish such as roach and bream. Populations of benthic invertebrates are affected, and roach populations have been in sharp decline for the past 10 years. One way to remedy the situation is to create natural spawning areas rich in macrophytes along the banks and around the Mosan islands in order to allow the development of calm areas rich in phytoplankton and fry.

Picture 3: Phytoplanktonic diatoms Asterionella formosa (source: DREAL Grand Est)

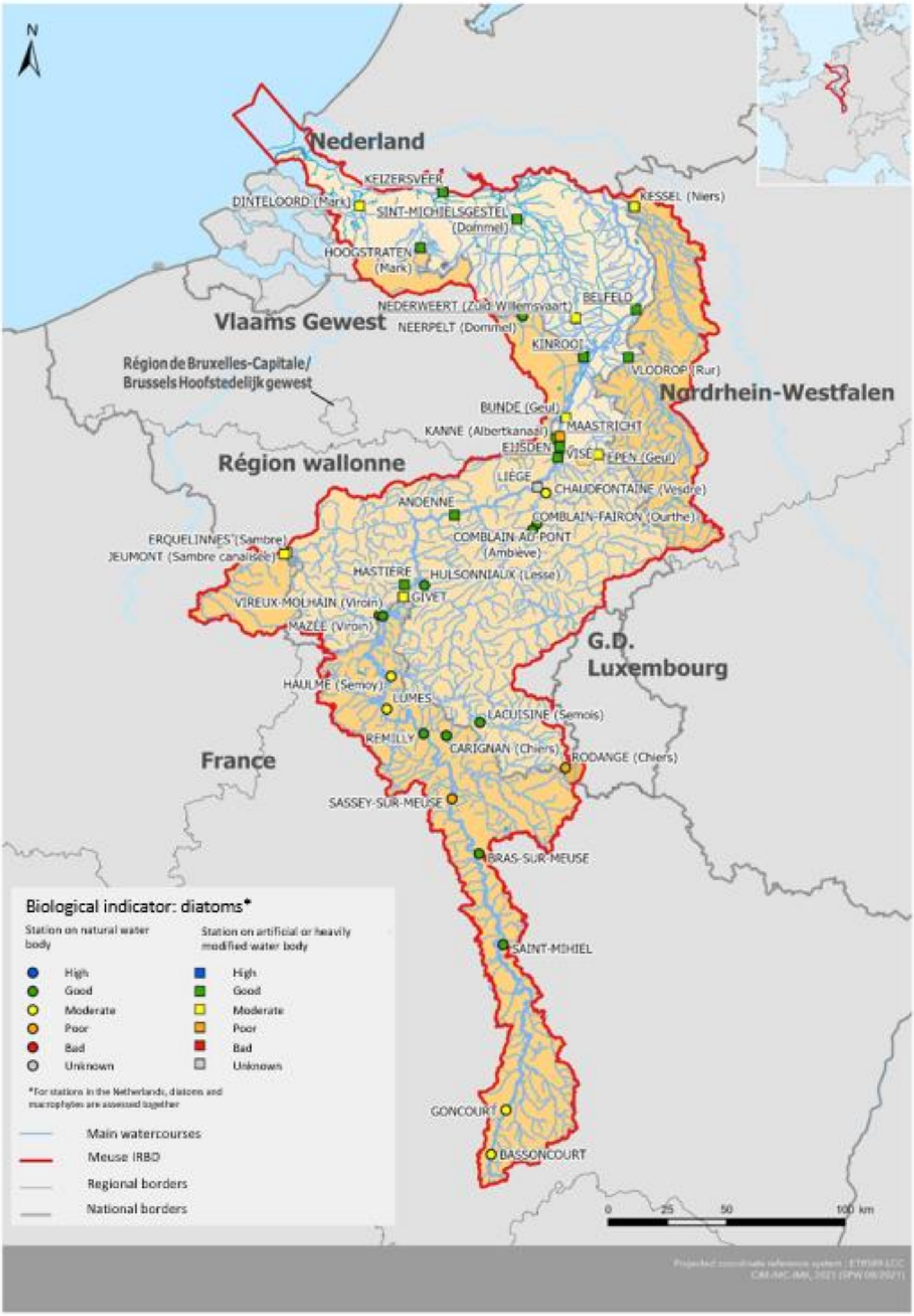
3.2. Benthic diatoms

Benthic diatoms are microscopic algae found on all submerged substrates of a river. They are excellent indicators of river water quality, particularly of organic pollution and eutrophication. They are used as an environmental assessment tool by all member states of the Meuse IRBD. Their evaluation in the HMR allows a map of the biological quality to be drawn up for the whole of the IRBD (see Map 5). It can be seen that 21 of the 37 stations assessed have a biological quality based on diatoms that is considered "good". The stations with a "moderate" quality for this indicator are spread over the entire Meuse catchment area. This could be explained by higher levels of organic pollutants and eutrophying agents at these sites.

It should be noted that in the Netherlands, the diatom and macrophyte indicators are assessed together, whereas they are assessed separately in the other countries.



Picture 4: Freshwater benthic diatoms (source: J.-P. Dutilleul)



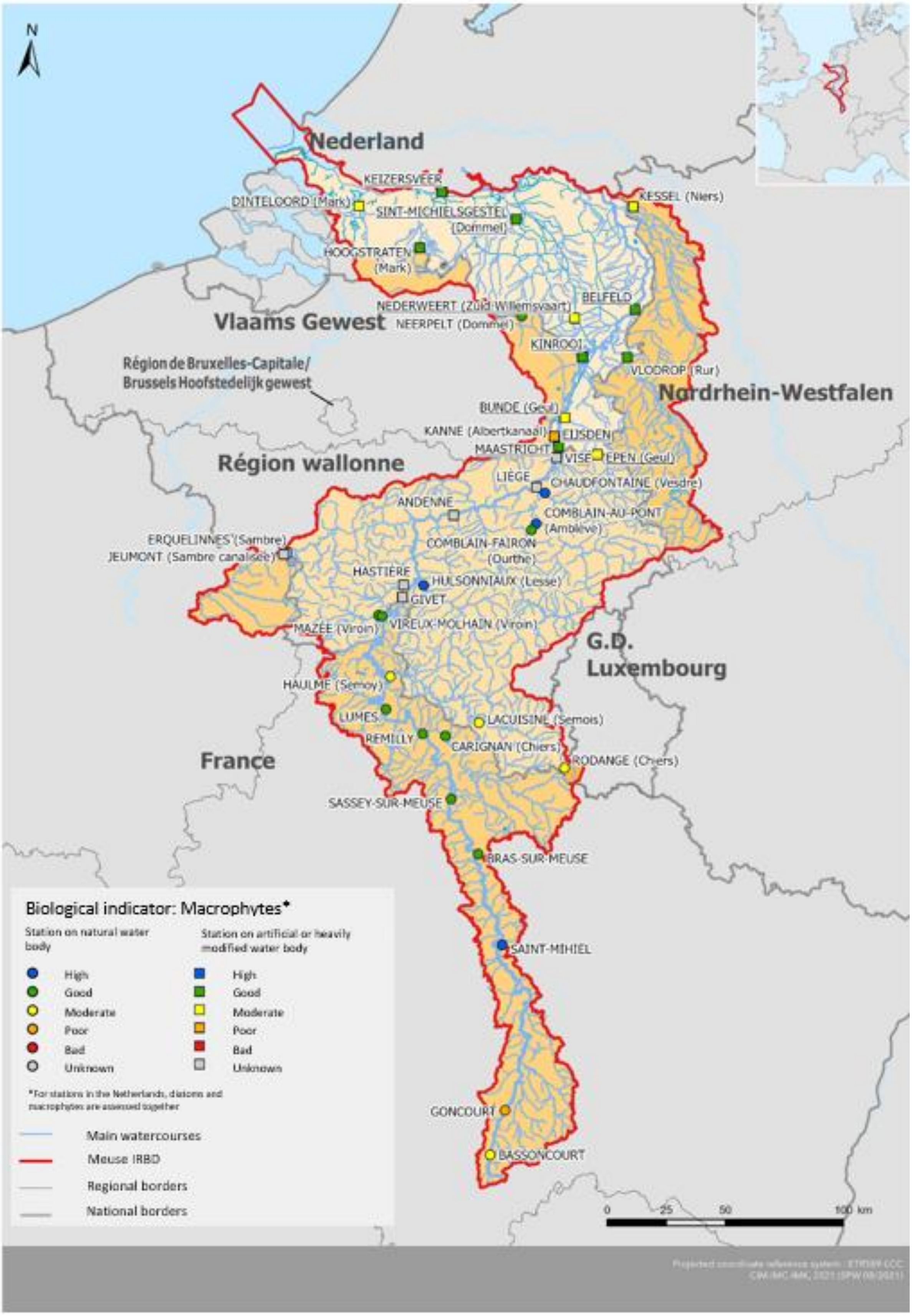
Map 5: Assessment of the biological quality element "Benthic diatoms" at HMR sites for the period 2017-2019.

3.3. Macrophytes

In France, with the exception of its first few kilometres, the Meuse has retained its most natural characteristics. In many areas, the riverbanks have a rich and diverse vegetation of aquatic plants. Various factors, such as hydraulic developments, eutrophication and increases in flow variations, have contributed to the decline or even the loss of aquatic vegetation in many sectors downstream of the Franco-Belgian border, although some of the main tributaries are of better quality (cf. map 6).

It should be noted that in Wallonia, macrophytes are only assessed in natural water bodies.

Picture 5: Azolla water ferns and Lemna duckweed (source: DREAL Grand Est)



Map 6: Assessment of the biological quality element "Macrophytes" at HMR sites for the period 2017-2019

3.4. Benthic macroinvertebrates

Benthic macroinvertebrates are larvae, nymphs and adults of animals without vertebrae (including many insects, molluscs, crustaceans and worms), which generally live at the interface between the water and the river bottom. Their development is largely conditioned by the quality of the water on the one hand, but also by the nature and diversity of the habitats available to them (rocks, stones, gravel, mosses, sand, flowing and calm zones, etc.). On large rivers, major developments related to navigation, hydroelectric production or flood protection often significantly alter benthic invertebrate populations by simplifying and reducing their habitats, flow diversity, etc. Since the implementation of the WFD, benthic macroinvertebrates have become a mandatory element in the assessment of the ecological quality of rivers.

Picture 6: Freshwater clam Sphaerium corneum (source: F. Chérot)

In 2017-2019, benthic macroinvertebrate communities in the HMR were rated as “good” to “very good” for 19 stations and “moderate” or “poor” for 16 stations (see Map 7). There has been no significant change in these figures over the last decade. The "good" or "very good" quality stations are mainly located in the French Meuse downstream of Neufchâteau as well as in certain tributaries of the Walloon Meuse such as the Viroin, the Semois, the Lesse and the Ourthe. The quality of the Meuse downstream of the Franco-Belgian border is ranked as "poor" for the benthic macroinvertebrate fauna. It is remarkable to note the recent disappearance of a large number of species usually observed and the homogenisation of communities. This loss of biodiversity, which was already fragile, may be linked to the invasion of the Meuse by a number of new, highly invasive species, including *Corbicula* spp and to the resulting disruption of trophic chains, as mentioned above.

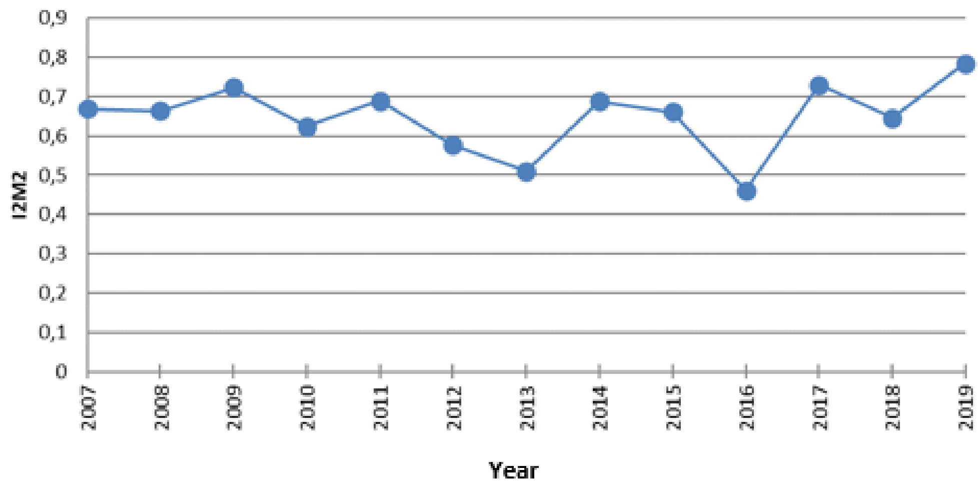


Figure 17: Temporal evolution of the macroinvertebrate indicator (I2M2[2]) at the Meuse site in Saint-Mihiel

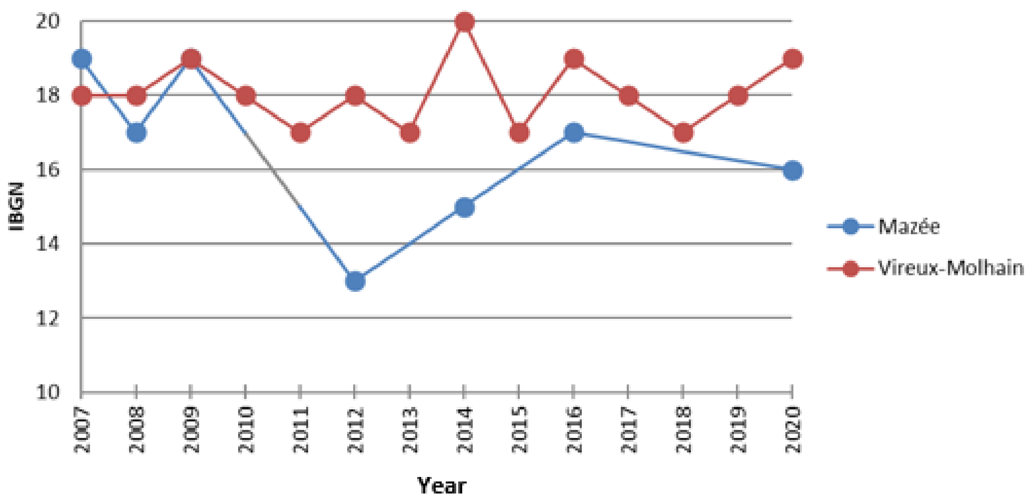
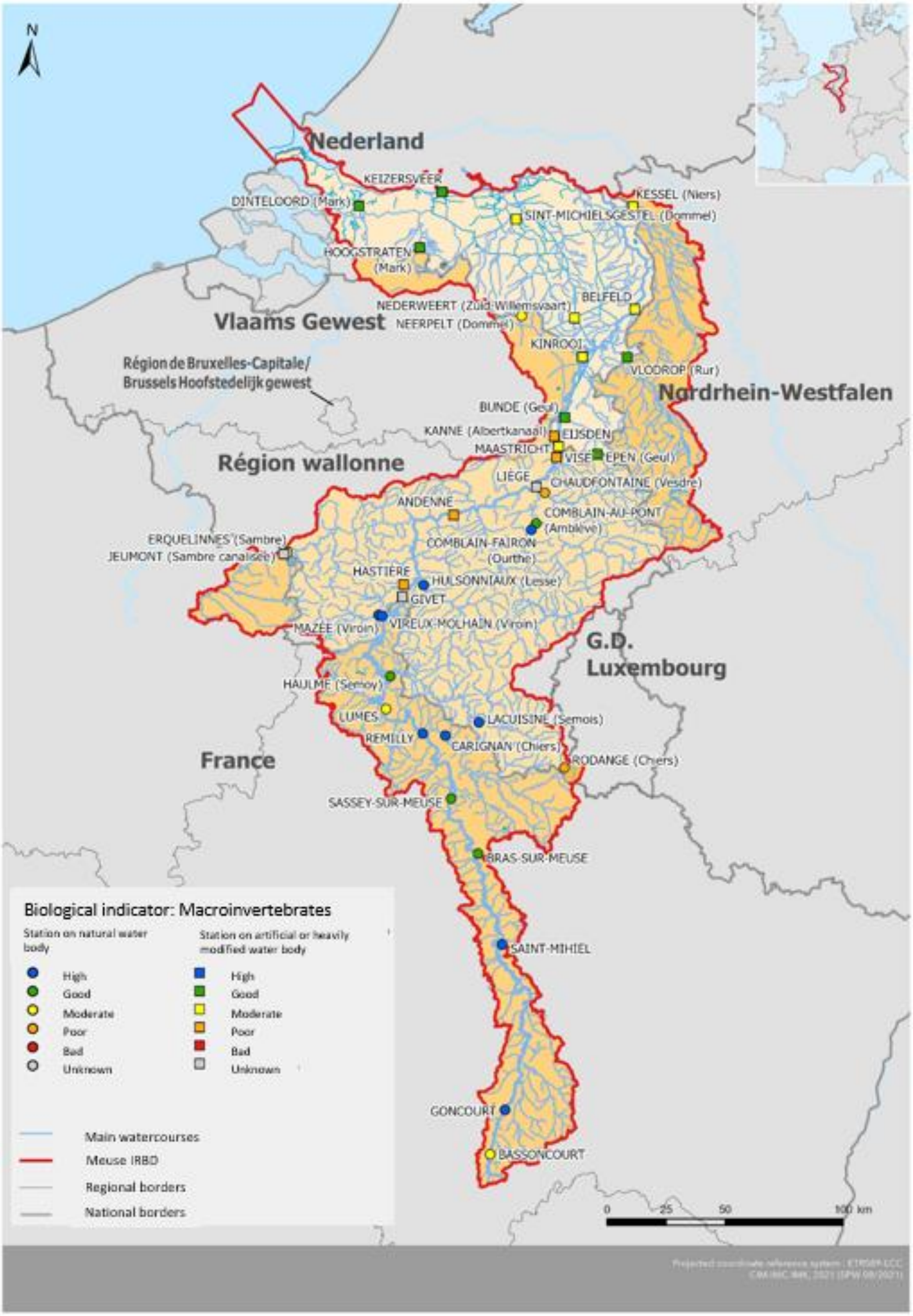


Figure 18: Temporal evolution of the macro-invertebrate indicator on the Viroin sites at Vireux-Molhain (IBGN-equivalent) (FR) and Mazée (IBGN [3]) (W)

[2] Multimetric invertebrate index.
[3] Indice Biologique Global Normalisé= Standardized Global Biological Index.



Map 7 : Assessment of the biological quality element "Macroinvertebrates" at HMR sites for the period 2017-2019.

3.5. Fishes

Fifty-two fish species are present in the Meuse IRBD, of which 36 are native. Many migratory species, such as the shad, have long since disappeared, while a few exotic species, such as the tubenose goby (*Proterorhinus semilunaris*) have recently invaded various Western European rivers and may account for up to 50% of the numbers in some places. Water pollution, overfishing, loss of habitat, limitation of small and large-scale movement possibilities, but also the arrival of exotic species have been, and sometimes still are, the causes of changes in native fish communities.

As for macroinvertebrates and aquatic plants, the situation is better in the French Meuse (middle section downstream of Neufchâteau) and in the Ardennes tributaries than in the Meuse downstream of the French-Belgian border, in Flanders and in the Netherlands (cf. map 8). In recent years, improvements have been slow and in some sectors the situation is deteriorating. The only tangible positive sign is the increasing number of salmon caught in the Lower Meuse over the last 5-10 years, as a result of an active policy of restocking and removal of obstacles to migration (see box).

Good water quality is an important factor for fish life in a river. But it is not the only one. The morphological quality of the river and the free movement of fish in the river are other factors. Free movement in the river is even more important for migratory fish such as, for example, salmon, sea trout or eels, which make longer or shorter journeys, or migrations, during their lives to complete their life cycle. The various IMC delegations are working to improve this free movement, in particular by collaborating within the ecology project group on a master plan for migratory fish in the Meuse basin. Several measures have already been taken in the past. As can be seen in figure 19, these measures have already had some positive effects in recent years, as the number of salmon caught at strategic points in the Meuse IRBD has increased significantly compared to the early 2000s. However, major efforts are still required in this area to ensure the survival of all fish species in our rivers, especially the eel, which is becoming increasingly scarce (Figure 20).

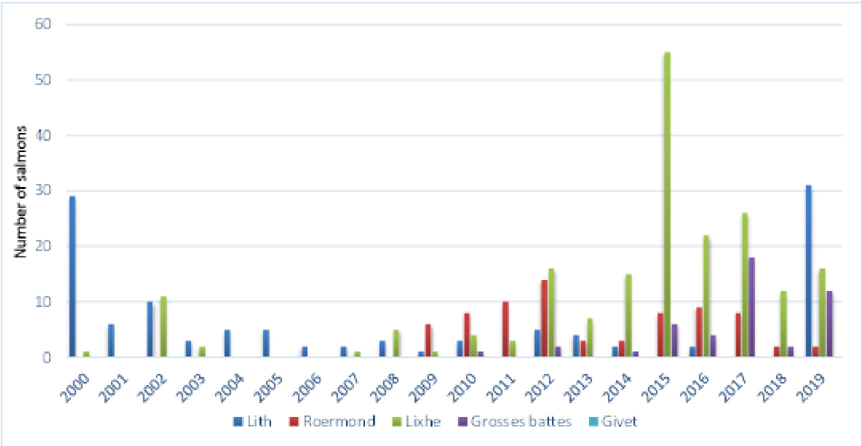


Figure 19: Evolution since 2000 of the number of adult salmon caught in upstream migration in 5 points of the Meuse IRBD

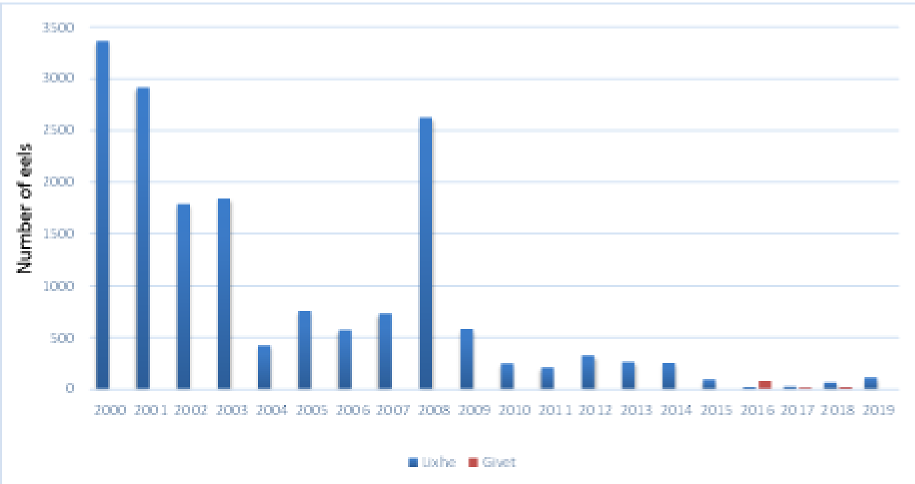
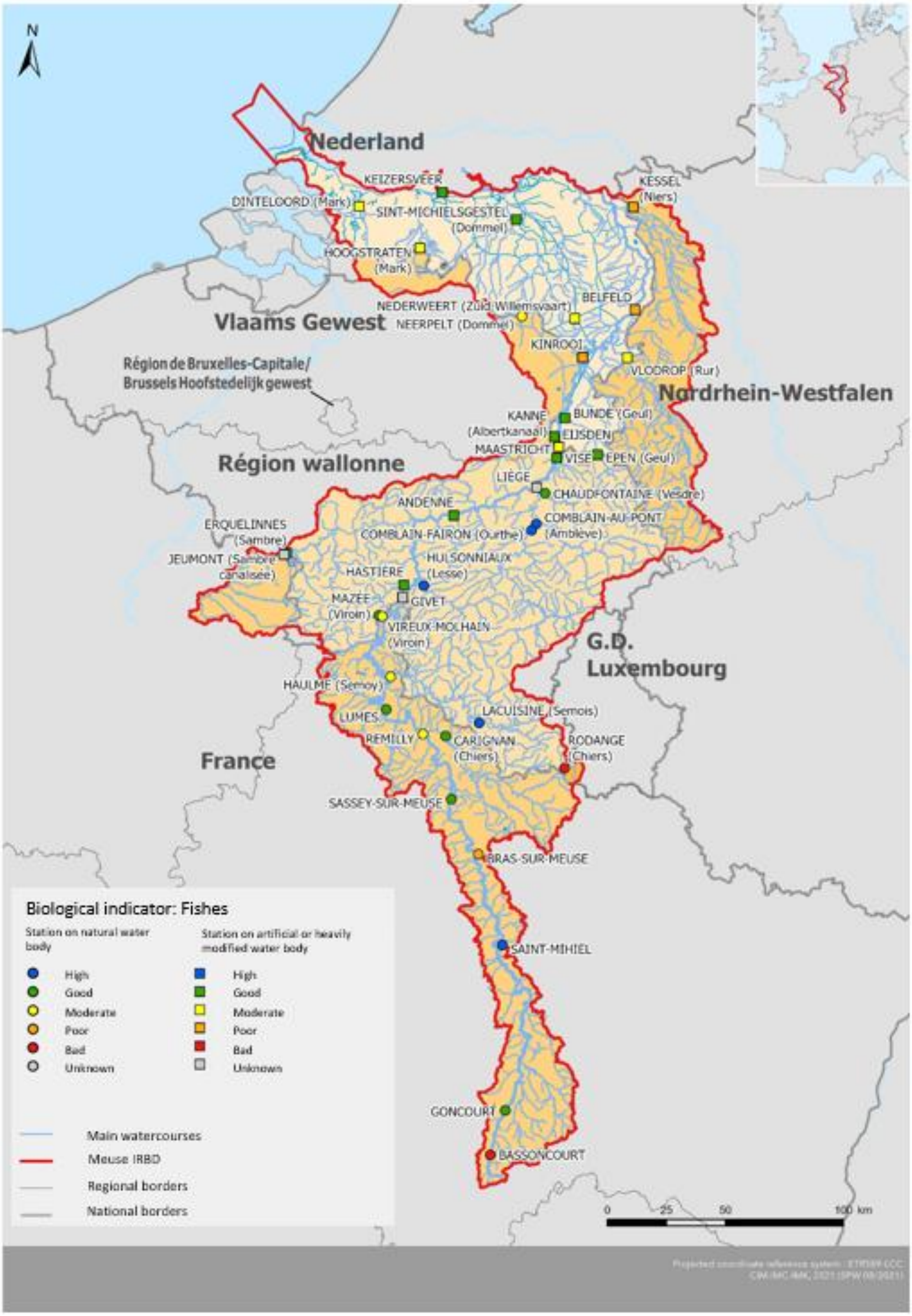


Figure 20: Evolution since 2000 of the number of yellow eels caught in upstream migration



Map 8 : Assessment of the biological quality element "Fish" at HMR sites for the period 2017-2019.

4. Evolution of the quality of the Meuse from 1996 to 2019 - Summary of the report

The quality of the main course of the Meuse and its main tributaries is jointly monitored at international level by the Meuse riparian countries in a "homogeneous measurement network" (HMR) with regard to various physico-chemical parameters and a number of biological parameters.

This report showed a generally positive evolution of the water quality of the Meuse and its tributaries since the end of the 1990s. This observation, already made in the previous report, is confirmed by the new data recorded for the period 2017 to 2019. Even though a three-year period is certainly too short to be able to draw definitive conclusions, we observe a continued improvement in the quality of the watercourses in the river basin.

In terms of macropollutants, this improvement is very clearly attributable to the efforts made by the States and Regions of the Meuse IRBD in the field of emission reduction. For example, the programmes to extend and improve urban wastewater treatment have made a significant contribution to reducing the dissolved oxygen deficits that were still often observed at the end of the last century. Nutrient concentrations are also decreasing, thanks in particular to the efforts made to treat urban pollution, but also in agriculture and industry. It should be remembered that, in the case of phosphorus, the evolution of the composition of detergents has largely contributed to this improvement. However, it is true that efforts still need to be made to reduce nitrogen inputs, particularly nitrates. Similarly, this overall improvement in quality must not hide the fact that certain problems remain, particularly on the tributaries of the Meuse, where efforts must be continued. In the future, particular attention should be paid to nitrogen and more specifically to nitrates in order to confirm that the recent increases are indeed due to exceptional meteorological events.

The situation is more mixed with regard to micropollutants. Concentrations of toxic substances such as certain heavy metals and PAHs remain problematic at many HMR monitoring stations. This is mainly due to the persistence and the way in which these compounds are disseminated.

We must also remain vigilant in the face of the arrival of new substances (known as "emerging substances") such as endocrine disruptors, whose effects on living communities are increasingly well known. The marketing of new synthetic molecules could also prove problematic in the future.

The effects of the efforts made by the States and Regions are least visible at the level of biological parameters. This can be explained in particular by complex pressure/impact relationships and by longer reaction times to improvements in this type of indicator. New pressures are also emerging. Exotic species, sometimes invasive, are threatening the balance of ecosystems, while global warming is posing a new threat to our rivers.

The management plans developed by the contracting parties to the IMC aim to reduce the impacts of current and future pressures in order to achieve good ecological and chemical status of all our rivers as soon as possible. Sustained efforts must be maintained to restore and renature watercourses that have been heavily modified, efforts to purify wastewater and reduce emissions must be continued, particularly in small watercourses, and the new threats posed by exotic species and global warming require the development of new and integrated management measures.

References

[1] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

[2] Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy amending and repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC.

[3] Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances for water policy.

[4] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources.

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December 2021