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Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures

Part II – development of a system of Europe-wide Pressure Indicators

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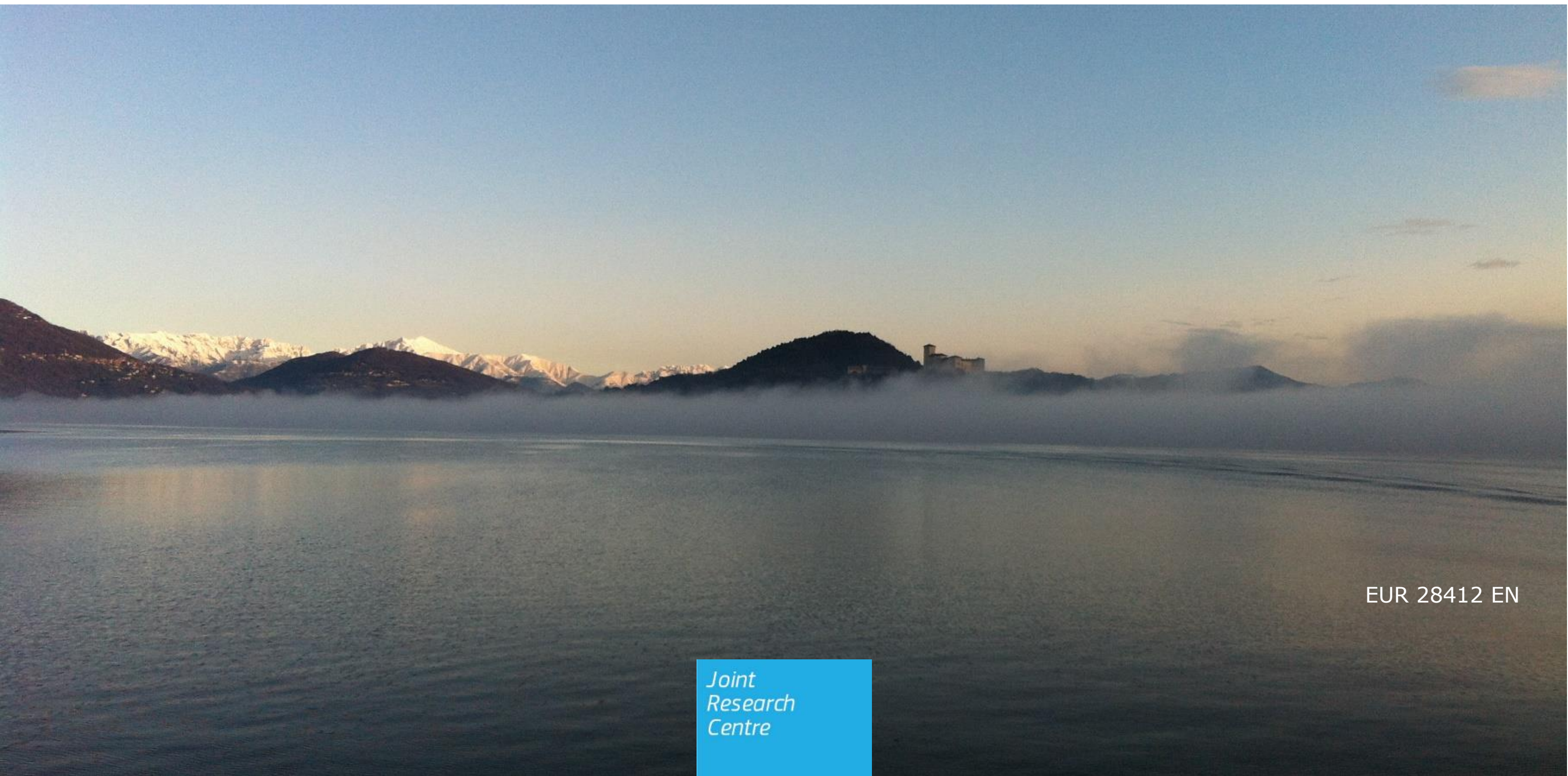

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Abstract

The EC DG JRC is using in-house models and other information to build indicators of pressures on water bodies, in the context of the 2nd river basin management plan (RBMP) implementation assessment (Water Framework Directive (WFD) 60/2000/EC, art. 18) and review of the WFD (art. 19). These indicators are meant to provide a picture of major water pressures at the European scale.

The main reason to develop a set of independent pressure indicators is the need to evaluate and monitor the effectiveness of the EU water policies at broad. If the indicators are realistic, the models used for their computation can be used also as tools to simulate scenarios with changing pressures, as a result of policies or other drivers (such as climate changes, implementation of measures or EU sectorial policies). The EC DG ENV is steering the development of an integrated hydro-economic modelling platform in support to the evaluation of policies, with the broadest possible involvement of the EU Member States, and collaborates with DG JRC by leading a large study on the economics of water in Europe also in order to supplement JRC's biophysical models and indicators with additional economic evidence about the costs and benefits of reducing pressures and improving the conditions of freshwater and marine ecosystems.

Another question is whether the pressures are evaluated consistently throughout the European Union. The JRC indicators could be used to benchmark pressure and status reported by the Member States at a different scale. In fact, if JRC indicators are sufficiently reliable, it is expected that overall trends will be consistent with the pressures reported by the Member States. At the same time, JRC indicators do not take into account local conditions in specific water bodies, and should not be compared to reported pressures and status at water body level.

DG ENV encourages Member States to provide feedback to DG JRC on the indicators and the underpinning models, so that the European scale picture of water pressures they provide can be improved to a sufficient level of realism and representativeness, and can be consequently used as a basis for European water policy evaluation and development. As a first opportunity for this process, the JRC organised a workshop in Ispra on 11-12 May 2016 with the aim to collect feedback from experts on the proposed methodologies and indicators. The JRC pressure indicators are updated over time, as new knowledge is available at the European level. Therefore the benchmarking of local and European assessments is supposed to be a continuous process.

The reviews by experts in the Member States should not add to the administrative burden related to the WFD, but should be conducted with the modalities of scientific peer reviews. It will be necessary to pay significant attention to the way the results are communicated, so to clarify the content of the indicators and avert risks of misinterpretation. The review of the indicators will serve also this purpose.

This document summarizes the JRC indicators, the state of play with their update and further development, and the outcomes of the workshop held in Ispra on May 11-12, 2016.

1. Introduction

The Water Framework Directive (WFD) 60/2000/EC requires the European Union Member States to ensure the non-deterioration in status of water bodies and achievement of a good status by 2015. To this end, an appropriate programme of measures (PoM) must be designed for each river basin district (RBD), in order to address previously identified pressures raising significant water management issues. Not achieving good status can be justified either if excessive efforts would be needed in comparison with the expected benefit, or if there is a prevailing value of the economic use of a water body over its status. In general terms, the commitment the European Union Member States took with the WFD is "to do as much as possible" to protect and improve the conditions of waters.

The 4th WFD Implementation Report[1] by the European Commission stresses the importance of scientific assessment, and particularly two essential pieces of knowledge to be tabled prior to the political discussion about PoMs: (1) a sound understanding of the status, and how it is affected by human pressures; (2) a gap analysis clarifying what would be required to achieve good status.

Yet, the Report observes "*that many Member States have planned their measures based on 'what is in place and/or in the pipeline already' and 'what is feasible', without considering the current status of water bodies and the pressures identified in the RBMPs as preventing the achievement of 'good status'. Instead of designing the most appropriate and cost-effective measures to ensure that their water achieves 'good status', thus tackling the persisting performance gap, many Member States have often only estimated how far existing measures will contribute to the achievement of the WFD's environmental objectives. This causes exemptions to be applied too widely and without appropriate justification. In most cases, when exemptions are applied and the achievement of 'good status' is postponed, it is not clear whether measures are taken to progress towards the objective, as required by the directive.*"

Over the years, DG JRC has been maintaining and developing a set of models and indicators that describe pressures on water bodies ranging from nutrient pollution, to hydrological regime, to chemicals. These have been used, *inter alia*, for the impact assessment of the Blueprint to safeguard Europe's waters[2]. Throughout this report, we refer collectively to this set of models and results as the "JRC pressure indicators".

The main reason for the European Commission to develop a set of independent pressure indicators is the need to evaluate and monitor the effectiveness of the EU water policies at the European scale. If the indicators are realistic, the models used for their computation can be used also as tools to simulate scenarios with changing pressures, as a result of policies or other drivers (such as climate changes, implementation of measures or EU sectorial policies).

Member States and river basin authorities have been using different tools for the characterization of pressures, including modelling, expert judgment, and a combination of both. The variety of possibilities in the assessment among Member States raises the question of how consistent the evaluation is across Europe. The JRC pressure indicators could be used to benchmark pressure and status reported by the Member States at a continental scale, although they do not necessarily take into account all local conditions that may be relevant in specific water bodies. For this reason they should not be compared to reported pressures and status at water body level.

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[1] COM(2015) 120 Final: http://ec.europa.eu/environment/water/water-framework/pdf/4th_report/COM_2015_120_en.pdf

[2] http://ec.europa.eu/environment/water/blueprint/index_en.htm; see also JRC supporting studies:
http://ec.europa.eu/environment/water/blueprint/pdf/EUR25552EN_JRC_Blueprint_Optimisation_Study.pdf
http://ec.europa.eu/environment/water/blueprint/pdf/EUR25551EN_JRC_Blueprint_NWRM.pdf

A preliminary and exploratory comparison of the JRC pressure indicators was drawn with the Reported Percentages of water bodies at Risk of not achieving the WFD goals by 2015 due to each category of pressures (RPRs), with reference to the 1st cycle of RBMPs (Pistocchi et al., 2015). The analysis did not aim at assessing the accuracy of reporting, and was purely *factual* and *non-judgmental*. It consisted of comparing the ranking of river basin districts (RBDs) (from high risk of not achieving the WFD goals to low risk) using RPRs reported by Member States with the ranking of European indicators of pressure (from high pressure to low pressure on the basin district) from pan-European data and assessments.

Besides the analysis of consistency of pressure assessment across the EU, this type of comparison supports the identification of knowledge gaps, which remains essential when evaluating the state of European waters. The overall goal is to have a coherent and shared vision of pressures at the European and river basin districts levels. This does not require complete accordance between national and EU assessments, considering the data and resolution at which they are developed, but a consistent "big picture".

The JRC has invited experts from European Union Member States to contribute, on a voluntary basis, to the examination of the proposed pressure indicators. The comments and criticism raised in this context will be used for their improvement. A first step of this examination was a workshop organized in Ispra during May 2016, of which the main outcomes are summarized in Annex 1.

The JRC pressure indicators are always in progress, to be updated as new knowledge is available at the European level, and so must be also for their scrutiny by the Commission and Member States.

In the context of the assessment of the 2nd cycle of RBMPs, it is desirable to achieve an overall picture of the link between pressures on, and status of European water bodies. While the specific knowledge of individual Member States and river basin authorities is necessary in order to capture specificities of individual river basins or water bodies, European scale analysis of the link between pressures and status may help achieving homogeneity and consistency in the continental "big picture".

This report describes the pressure indicators proposed by the JRC, including concentrations and loads of nutrients derived from EPIC and GREEN models, water balance components derived from the LISFLOOD model, and hydro-morphological pressure indicators under present conditions. Results will be disseminated for review by EU Member States, and subject to revisions based on feedback. This review of JRC model results will make them ready for use in support of the Commission's 5th WFD Implementation Report (WFD art. 18). After an overview of the indicators proposed for the different reported pressures, we briefly summarize the methods, preliminary applications and state of play with the individual JRC pressure indicators.

2. Pressures and pressure indicators

The WFD Reporting Guidance 2016[3] lists 56 types of pressures on water bodies that member states may report as causing not achieving the WFD objectives (Table 1). At least one significant type of pressures, and the impacts it generates, should be reported for each water body where the status is less than good.

Many of these types of pressures may be specific to individual situations in European river basins, and cannot be compared with European indicators: Member States (MS) reports are the only available information source. For some, however, sufficient information is available in order

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[3] http://cdr.eionet.europa.eu/help/WFD/WFD_521_2016/Guidance/WFD_ReportingGuidance.docx

to draw a picture at European scale (for instance, diffuse pollution from agricultural sources of nutrients).

We should stress once more that the JRC pressure indicators are results of model calculations or processing of available spatial datasets at European scale, independent of the information reported by Member States under the WFD. They aim at mapping situations where a certain pressure *might* hamper the achievement of water body status objectives set by the WFD. While pressures represent human activities generating a change in status (e.g. emissions of chemicals alter concentration in water bodies), in this work we refer with "pressure indicator" to any variable that may suggest potential difficulties with achieving the WFD objectives. Variables of this type include predicted concentrations of nutrients or chemicals, or hydromorphological alteration metrics.

Table 1 indicates the JRC pressure indicators proposed for each pressure type. In some cases, the proposed indicator corresponds to several pressures types. For example hydrological alteration is represented through indicators reflecting the sum of all abstractions and not individual sectors' ones, and the indicator of dams does not differentiate among the purposes of the dams. Therefore, in the table there may be a single indicator for a group of more than one pressure identified in the WFD Reporting Guidance.

In Table 1, we display in green the pressures for which a pertinent indicator exists at pan-European scale (possibly requiring to be updated). A second category of pressures, shown in yellow, includes those deemed a priority to be addressed at pan-European scale, but presently not reflected in JRC indicators. Additional indicators for these pressures are being (or will be) developed in the context of ongoing JRC work. Therefore, the JRC strives to provide them in the course of the assessment of the 2nd RBMPs by the European Commission, compatibly with available resources. Both for green and yellow pressures, certain indicators stem from well-established methods and peer-reviewed scientific analyses, whereas other indicators are being developed as part of the research conducted at the JRC. These indicators need to be appropriately tested before they can be reliably used. They are displayed in red in Table 1. The JRC strives to test them in the course of the assessment of the 2nd RBMPs by the European Commission, compatibly with available resources.

The remainder of this report provides a short overview of the individual indicators listed in the table, as well as the essential information on the models and methods used for their calculation. Additional details may be found in the references cited through the report, and will be presented in the specific discussions to be held in the course of consultations with the experts from Member States.

While, ideally, the indicators should enable a comparison with reported pressures at the individual water body level, this will not be generally possible due to the relatively coarse resolution of European-scale assessments. Therefore an appropriate strategy for comparison needs to be devised. This will be discussed at a later stage of the work.

Pressure type	**SW or GW?**	**Proposed indicators**[4]	**Methods**	**Ref. §**
1.1 - Point – Urban waste water	SW	N, P, BOD, TSS or priority chemicals concentration calculated from urban point sources only	GREEN model, GREEN+ model for BOD, TSS and priority chemicals	3.1, 3.2, 3.3

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[4] In general, indicators representing concentration are not pressure indicators; only when they exceed a threshold they can indicate that the pressure is high. We will refer to concentrations as a proxy of the intensity of pressure from specific pollution sources, to be interpreted in the light of available environmental quality standards as far as possible.

Pressure type	**SW or GW?**	**Proposed indicators**[4]	**Methods**	**Ref. §**
1.2 - Point - Storm overflows	SW	N, P, TSS and BOD concentrations from combined sewer overflows	Specific analysis using urban runoff estimation from LISFLOOD	8
1.3 - Point - IED plants	SW	N, P, BOD, TSS or priority chemicals concentration calculated from E-PRTR emissions only		3.1, 3.2, 3.3
1.4 - Point - Non IED plants	Not addressed at European scale			
1.5 - Point - Contaminated sites or abandoned industrial sites				
1.6 - Point - Waste disposal sites				
1.7 - Point - Mine waters				
1.8 - Point – Aquaculture				
2.1 - Diffuse - Urban run-off	SW	*Dilution ratio of urban runoff in rivers*	Specific analysis using urban runoff estimation from LISFLOOD	8
2.2 - Diffuse – Agricultural	SW, GW	SW: Worst among N, P, concentration calculated from agricultural diffuse sources only; GW: N loss from fertilization	SW: GREEN model; GW: EPIC model	3.1 (SW); 6 (GW)
2.3 - Diffuse – Forestry	SW	N, P, concentration calculated from forest diffuse sources only	GREEN model	3.1
2.4 - Diffuse – Transport	Not addressed at European scale			
2.5 - Diffuse – Contaminated sites or abandoned industrial sites				
2.6 - Diffuse - Discharges not connected to sewerage network	SW	N, P, BOD, TSS or priority chemicals concentration calculated from scattered dwelling sources only	GREEN model, GREEN+ model for BOD, TSS and priority chemicals	3.1, 3.2, 3.3
2.7 - Diffuse - Atmospheric deposition	SW	N concentration calculated from atmospheric deposition only	GREEN model	3.1
2.8 - Diffuse – Mining	Not addressed at European scale			
2.9 - Diffuse – Aquaculture				

Pressure type	SW or GW?	Proposed indicators[4]	Methods	Ref. §
3.1 – Abstraction or flow diversion – Agriculture 3.2 – Abstraction or flow diversion – Public water supply 3.3 – Abstraction or flow diversion – Industry 3.4 – Abstraction or flow diversion – Cooling water 3.5 – Abstraction or flow diversion – Hydropower	SW	WEI+ (consumption) WEI+ (abstractions) Flow alteration (10%-ile) Flow alteration (25%-ile)	LISFLOOD hydrological model; *ad-hoc* GIS calculations	4
3.6 – Abstraction or flow diversion - Fish farms				
4.1.1 - Physical alteration of channel/bed/riparian area/shore - Flood protection	SW	Artificial land cover in floodplains Density of infrastructure in floodplains Riparian veg. buffer width / floodplain width	*Ad-hoc* GIS calculation	5
4.1.2 - Physical alteration of channel/bed/riparian area/shore – Agriculture	SW	Agricultural land cover in floodplains	*Ad-hoc* GIS calculation	5
4.1.3 - Physical alteration of channel/bed/riparian area/shore – Navigation	Not addressed at European scale			
4.2.1 - Dams, barriers and locks - Hydropower 4.2.2 - Dams, barriers and locks - Flood protection 4.2.3 - Dams, barriers and locks - Drinking water 4.2.4 - Dams, barriers and locks - Irrigation 4.2.5 - Dams, barriers and locks – Recreation 4.2.6 - Dams, barriers and locks – Industry 4.2.7 - Dams, barriers and locks – Navigation	SW	Indicators of dam impact, e.g.: % catchment area intercepted by dams % Length of stream segment that is dams-free	*Ad-hoc* GIS calculation	5
4.3.1 - Hydrological alteration – Agriculture (e.g. land drainage)	Not specifically addressed at European scale (see pressures of type «abstraction or flow diversion»)			
4.3.2 - Hydrological alteration – Transport (e.g. navigation)				
4.3.3 - Hydrological alteration – Hydropower (e.g. hydropeaking)				
4.3.4 - Hydrological alteration – Public water supply				
4.3.5 - Hydrological alteration – Aquaculture				
4.4 - Hydromorphological alteration - Physical loss of whole or part of the water body				
5.1 - Introduced species and diseases	SW	*Indicators to be defined (limited to invasive alien species)*	*Information from JRC EASIN*[5]	9
5.2 - Exploitation or removal of animals or plants				

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[5] http://easin.jrc.ec.europa.eu/

Pressure type	SW or GW?	Proposed indicators[4]	Methods	Ref. §
5.3 – Litter or fly tipping	SW	*Indicators to be defined*	*JRC exploratory research ongoing*	9
6.1 - Groundwater – Recharges	Not addressed at European scale			
6.2 - Groundwater – Alteration of water level or volume	GW	*Groundwater volume deficit indicator*	LISFLOOD	7
9 - Anthropogenic pressure - Historical pollution	Not addressed at European scale			

Table 1 –Pressure types causing non-achievement of WFD objectives, and corresponding proposed JRC Pressure Indicators. This table does not list "unknown" or "other" pressures (Annex 1 of the WFD Reporting Guidance 2016) that are, by definition, those not amenable to pan-European indicators. SW=surface water bodies; GW= groundwater bodies.

3. Surface water quality

Indicators of surface water quality include concentrations of nutrients, total suspended sediments (TSS), oxygen-depleting substances as biochemical oxygen demand (BOD), and concentrations of priority chemicals. Nutrients are relatively well-studied at pan-European scale; BOD and TSS are not yet modelled at pan-European scale, but their monitoring and understanding is well-established at national and regional level in Europe. Priority chemicals are far less studied at pan-European scale, and present a number of specific aspects to be addressed in each river basin district. The models used for calculation allow distinguishing by emission source. Therefore it is possible to compute concentrations arising from *one emission source category at a time* (point/diffuse, urban/industrial/agricultural/forestry/atmospheric deposition), or concentrations resulting from all sources together.

3.1 Nutrients

3.1.1 Methodology

The GREEN model (Geospatial Regression Equation for European Nutrient losses; Grizzetti et al. 2012; Bouraoui et al. 2011) is used to predict annual loads of nitrogen (N) and phosphorus (P) from point and diffuse sources.

The model starts from inventories of point source emissions and diffuse emissions, aggregated at sub-basin level. Point source emissions are directly released to the stream network, whereas diffuse emissions are supposed to reach the stream network through runoff (surface and groundwater are lumped together), after a basin retention. The current version of the model does not account for retention of nutrients in aquifers and their lagged release to surface waters. While the problem is relatively straightforward with reference to specific river basins, research is ongoing about how to parameterize this process at pan-European scale.

In each sub-basin the model computes the nutrient load and the share of point and diffuse emissions, which are then transferred downstream, taking into account the retention occurring in the stream network.

Concentrations are obtained by dividing loads by appropriate streamflow discharges. One option is to use the annual average runoff, which can be estimated as the difference of annual precipitation and estimates of actual evapotranspiration from a Budyko-type model (Bouraoui et al. 2009; Grizzetti et al. 2012).

3.1.2 Spatial and temporal resolution

The spatial resolution of the model is the unit of the sub-basin, a portion of the river basin with average surface area of around 180 km^2 (HYDROEUROPE v1 Database: Bouraoui et al. 2011).

The model provides a yearly average load of N and P. This can be divided into load originated from different sectors: point sources, agriculture, atmospheric deposition or background.

3.1.3 Input

Point sources: inventories of wastewater treatment plant emissions, industrial emissions and scattered dwellings (see Box 2 for details).

Diffuse sources: mineral fertilizer and manure application rates, estimated by the CAPRI model[6] (year 2005). Atmospheric deposition is included in the calculations (source: EMEP model). Emissions from scattered dwellings (estimated from population not connected to the sewerage system).

3.1.4 Preliminary assessment

The following figure shows example maps of N and P concentration (average for the year 2005) calculated with the current version of GREEN.

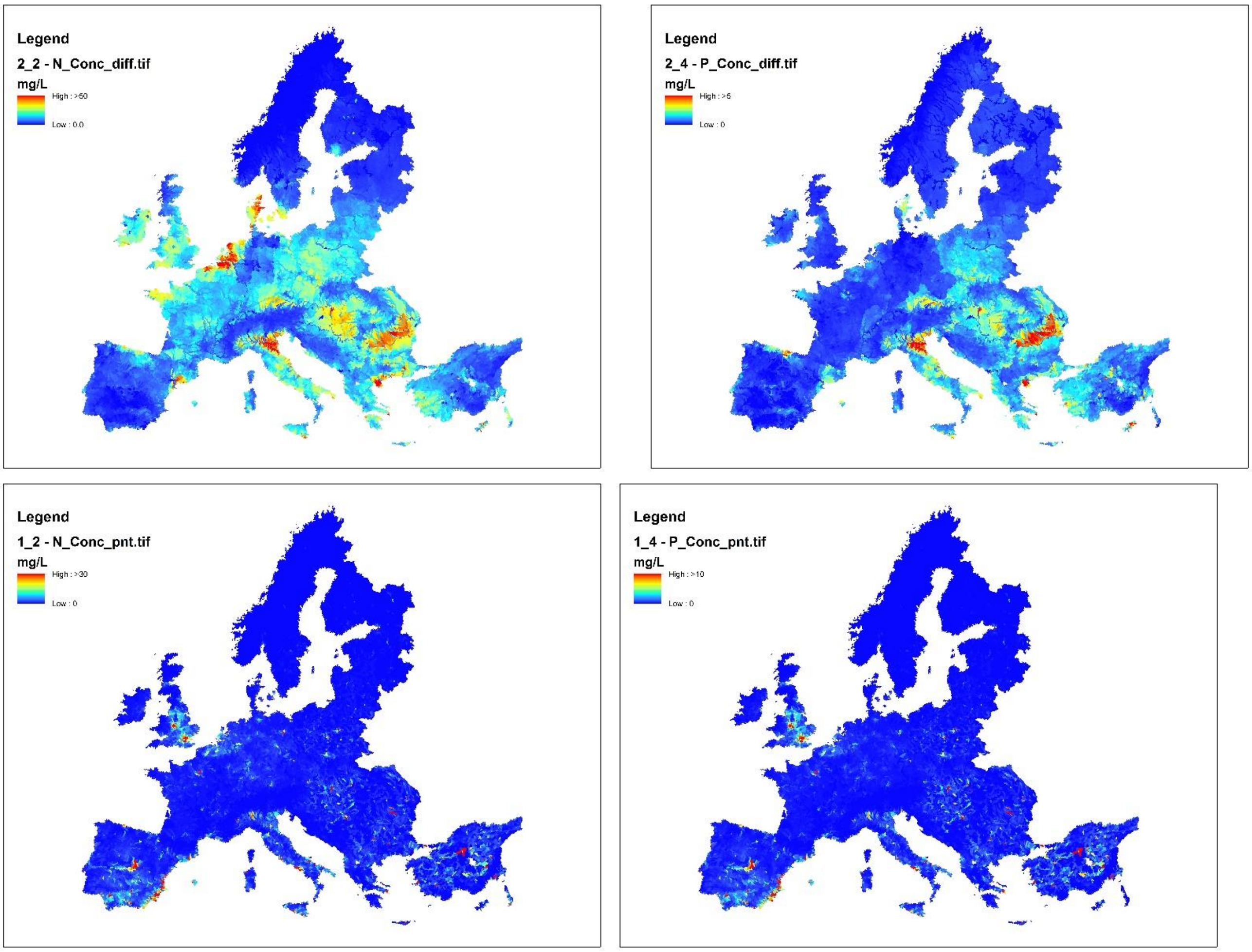

Figure 1 –N (left) and P (right) concentration maps from GREEN (2005 average), accounting for point (below) and diffuse (above) sources separately.

3.1.5 Previous applications

1. quantification of nitrogen and phosphorus loads to all European seas from 1985 to 2005, including an analysis of the effects of European policies on the water quality (Grizzetti et al. 2012);

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[6] http://www.capri-model.org/

2. analysis of future scenarios of policies implementation at European scale (Bouraoui et al. 2014);
3. assessment of risk of nitrogen water pollution on human health and aquatic ecosystem functioning (euthrophication) (Grizzetti et al. 2011; Leip et al. 2015);
4. quantification of ecosystem services related to aquatic ecosystem (water purification in rivers) (La Notte et al. 2015; Liquete et al. 2015);

The results of this research have been used by the European Commission in the report on the implementation of the Nitrates Directive (European Commission 2007), and by the European Environment Agency in the Report on the Status of Environment 2010 (European Environment Agency 2010).

Recently[7], GREEN has been benchmarked against MONERIS and SWAT models in the Danube, in the context of the assessment of nutrients for the Danube River Basin Management Plan (Malago et al. 2015) and against RiverStralher and SWAT models in the Seine river basin (Grizzetti et al. 2015).

3.1.6 Strengths

- Robust estimation of annual nitrogen and phosphorus loads, concentrations and source apportionment
- Cover all EU consistently, with high spatial resolution
- Conceptually simple/transparent
- Analysis at the river basin scale and sub-catchment scale
- Can be used to test the effect of changes in nutrient inputs from various sources at different spatial location

3.1.7 Weaknesses

- Statistical regression model that relies on measurements
- Annual nitrogen and phosphorus load but not seasonal information
- No memory, lag time estimation
- No physical processes thoroughly represented

The resolution of the model, corresponding to sub-basins, does not allow comparison with individual water bodies. A criterion to aggregate reported pressures on individual water bodies for each sub-basin will have to be defined.

3.1.8 State of play

Indicators given by loads and concentration of N and P are available for Europe based on model input updated to 2005 as a base year. Work is ongoing at the JRC to incorporate:

- updated estimates of nutrient applications from the CAPRI model (base year 2008, in future 2012 will be also available from CAPRI).

- update atmospheric deposition (year 2008-2010).

- increase the number of observations (water quality measurements) to calibrate the model (we are evaluating the possibility to use the EEA Waterbase)

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[7] http://publications.jrc.ec.europa.eu/repository/handle/JRC99193

Point sources (wastewater treatment plants, collected but untreated emissions, industrial emissions from E-PRTR) have been updated using the data available from EEA for the reporting year of 2012 (see details in Box 2 below).

Nutrient concentrations should be interpreted in the light of appropriate environmental quality standards. Nutrient standards have been defined by Member States with reference to specific water body typologies, and will be taken into account as far as possible.

As a follow up of the workshop in May 2016, several activities have been undertaken to improve the representation of pressures related to point and diffuse pollution:

1) **Higher spatial representation of the river network:** A new hydrological data model (called HydroEurope2) has been developed based on the CCM2[8] to delineate the sub-catchments within each river basin with higher spatial resolution.

2) **Include quality measurements reported by Member States to EEA:** Water quality data reported by the Member States in the EEA Waterbase (river data version 14[9]) have been linked to the river network.

3) **Check and update fertilizer applications:** The most recent data from CAPRI refer to year 2008. They were compared to the information of 2005 used in the modeling, and to the data reported by FAO and IFA. As applications between 2005 and 2008 have not changed dramatically, it was decided to wait for the CAPRI data for year 2012 to become available.

4) **Check and update point sources:** Emission loads from point source and scattered dwelling were estimated using data reported by Member States to European databases (see details in the textbox below).

Textbox: **Estimation of point source and scattered dwelling emission loads using European databases**

Two databases that are maintained and published by the European Environmental Agency (EEA) were used to estimate emissions from point sources: the Waterbase - Urban Waste Water Treatment Directive reported data (UWWTD; EEA 2016a) and the European Pollutant Release and Transfer Register (E-PRTR; EEA, 2016b).

The UWWTD reports annual loads in terms of person equivalents (PE) that are produced in agglomerations larger than 2000 PE, collected, treated and discharged. The year of reference for v9 used for this study was 2011-2012. Data is reported for 28 EU Member states, Switzerland and Norway. Countries are responsible for collection and transmission of the information to the EEA. Location of agglomerations, UWWT plants and discharge points are reported, as well as the type of treatment of UWWT plants. Transfers occurs in a complex network, and sometimes tables are incomplete. Incoherent load transfers were detected in analyzing the database; with a discrepancy amounting to 19M PE (3% of load collected at agglomerations) and the importance of inconsistencies varied among Countries. The inconsistencies were addressed at the best of our possibilities by re-tracing the logic of the database (e.g. Amparore, 2012). The total discrepancy was reduced to 2.5M PE (0.4% of collected load), however a number of assumptions had to be taken during the procedure, so that emission loads estimated at the discharge points may differ from those reported in the original database. In the end, PE emissions were calculated for 28607 discharge points, which comprise also 565 UWWTP whose discharge point was unknown, and whose discharge point was assumed to coincide with the UWWTP location.

Five-days Biological Oxygen Demand (BOD5), Total Nitrogen (TN), and Total Phosphorus (TP) annual loads,

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[8] http://ccm.jrc.ec.europa.eu/php/index.php?action=view&id=23

[9] http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-10

in t/y, were estimated on the basis of treated PE and type of treatment as follow. UWWTP incoming BOD load was assumed equal to 60g BOD /PE/day according to the definition of PE assumed in the UWWTD. Incoming TN and TP were estimated according to national statistics of protein consumption (Jönsonn and Vinnerås, 2003; Bouraoui et al., 2011; Morée et al., 2013). Protein supply statistics were derived from FAO (FAOSTAT 2009-2011 data). Retail losses, sweat/hair and sewer losses were set as suggested by Morée et al. (2013). For P emissions, P in detergents was considered as in Bouraoui et al. (2011). Emission loads considered efficiency of UWWT plants. The UWWTD database reports primary, secondary or other treatments. Efficiencies for treatment level were set according to literature (Nelson and Murray, 2008; Powley et al., 2016) and used to calculate emission loads. The UWWTD reports for a minority (< 7500 of 30044) UWWTPs incoming and emission loads. The reported data were compared to the estimations and were found in good general agreement. Finally, emission loads were transferred to discharge points. In the cases where a given UWWTP had two or several discharge points, emissions were allocated proportionally to the estimate reach mean streamflow, so that larger rivers received larger loads.

Industrial releases are reported in E-PRTR database and comprise information about facility type, releases to air, water and soil, for 99 chemicals. The database reports facility location, type, released loads and transfers from 30 Countries, including the 28 EU MS, Switzerland, Norway, Serbia and Iceland. Data reported in v9 and used for this study span from 2001 to 2014. The 2014 reporting period provide the largest number of reported facilities and Countries. To assess 2012 loads the mean over the 5-year period 2010-2014 was used. UWWTPs reported in this database for the Countries already reporting in UWWTD were excluded from the analysis. Released loads net of transfers for TN and TP were directly derived from the database. BOD5 loads are not reported, however Total Organic Carbon (TOC) loads are. BOD5 were estimated as 1.85TOC based on molecular weight equivalence loads without being able to consider the heterogeneity of facility releases (Dubber and Gray, 2010). Releases were allocated to the facility sites since no information was available in relation to eventual discharge points.

Emissions from scattered dwellings were estimated in the basis of population density and national statistics of connection percentage, attributing the disconnected portion of population to the less populated area of each Country. The Global Human Settlement Layer (GHSL) project of European Commission, Joint Research Center and Directorate-General for Regional and Urban Policy (Freire and Pratesi, 2015) reports global population density (inhabitants/km^2) at resolution of 1 km^2 or 250 m. For this study the 2015 population at 1 km^2 resolution was used. National statistics of percentage of connected population were retrieved from EUROSTAT (2016), UN (2011), and Bouraoui et al. (2011). The fraction of disconnected population was attributed to the less populated areas, setting national thresholds of maximum population density for the presence of scattered dwellings. The population in areas below the density thresholds was considered equal to scattered dwelling person equivalent loads, and amounted to 96.6. MPE for the enlarged Europe. The calculation of emissions proceeded then as in the case of UWWTD point sources to assess incoming loads of BOD5, TN and TP. Scattered dwelling loads were assumed to be processed in septic tanks. Efficiency of septic tanks was assumed at 35% for BOD5, 25% for TN and 30% for TP after Nelson and Murray, 2008).

3.2 Chemicals

3.2.1 Methodology

Chemicals under the WFD include:

- priority substances, of EU level interest;
- river basin-specific pollutants.

The CIS Guidance document n. 28 "Technical Guidance on the Preparation of an Inventory of Emissions, Discharges and Losses of Priority and Priority Hazardous Substances"[10] provides indications for member states on the preparation of emission inventories.

The JRC Pressure Indicators *focus on priority substances* as discussed below, and consist of maps of Predicted environmental concentrations (PECs) of priority substances (one per substance). The proposed approach follows the "riverine load" concept of Guidance document n. 28, and consists of two modelling steps:

1) inverse modelling of observed loads in order to derive maps of emissions;
2) spatially explicit calculation of predicted environmental concentrations (PECs) from those emission factors.

The first step requires comparing observed loads at a number of sample points with appropriate indicators of human activity in the catchment of each sample point ("emission pattern"). We approximate the relationship between the emission pattern and the observed loads as linear, and the slope of the relationship represents the "emission factor". In the simple case of a conservative chemical emitted homogeneously by households, for instance, catchment population could be used to represent potential emissions. In the example of population, this would be read as the emission *per capita* in the catchment (Figure 2).

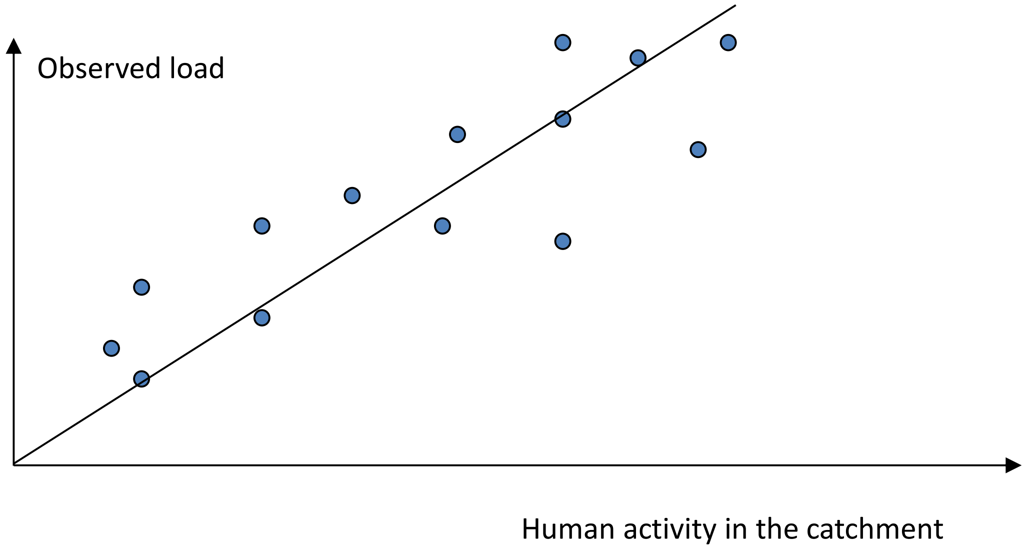

Figure 2 – comparison of an indicator of human activity in the catchment, with the observed load of a contaminant at the outlet of the catchment.

The model can be adjusted to account for the spatial distribution of emissions within the catchment and the time of travel from each location in the catchment, to the monitoring point. We take into account chemical dissipation through an exponential decay depending on the travel time of contaminants in the catchment, and we allow emission patterns to follow different sources (e.g. agriculture, livestock, etc.) or a combination of sources.

Details on the method are provided in Pistocchi and Loos, 2009, for conservative chemicals (specifically, PFOA and PFOS), and Pistocchi et al., 2012, and chapter 19 of Pistocchi, 2014, for chemicals subject to decay. The approach is conceptually similar to GREEN as discussed above. The main difference is that, while GREEN assumes an inventory of nutrient emissions as an input to the model, for chemicals we assume emission to be proportional to a pattern in space (e.g. population) and we infer the proportionality constant (or emission factor) based on

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[10] https://circabc.europa.eu/sd/a/6a3fb5a0-4dec-4fde-a69d-5ac93dfbbadd/Guidance%20document%20n28.pdf

monitored concentrations. Examples of typical emission patterns considered in practice are listed in Table 2.

Pattern	**Represented types of chemicals**
Agricultural land use	Pesticides
Population	Generic technosphere chemicals, urban runoff
Collected population (only population captured by sewage systems)	Human pharmaceuticals, household chemicals through wastewater treatment
Livestock (possibly disaggregated into Cattle, Pigs, Poultry, Sheeps+goats)	Veterinary pharmaceuticals
Atmospheric deposition	Airborne multimedia chemicals

Table 2 – typical emission patterns used for chemical modelling.

Once the emission factor is known, it is possible to use the emission pattern to map emissions and loads explicitly. Concentration follows from dividing by a representative discharge as pointed out for GREEN. For instance, if emissions per capita are known, we can map loads based on population, and concentrations dividing loads by water discharge. The calculation of loads is obtained through a simple steady state, plug-flow transport model (Pistocchi, 2014, ch. 19) enabling the routing of emissions along the stream network, including the effect of lakes and reservoirs.

Typically, emission factors are characterized from a number of measurements, and the effect of point emissions is often hidden in the variability of the data. Therefore, it can be assumed that the emission factors reflect the "diffuse" component only of these emissions (see e.g. Pistocchi and Loos, 2009). When significant point emissions are known, they can be included in the calculation of concentrations in addition to diffuse emissions.

This approach must be regarded as an exploratory tool allowing an independent evaluation of a set of available chemical concentration/load measurements. The calculation of concentrations does not reflect a number of chemical fate and transport processes (e.g. adsorption to particulate matter or sediment. Therefore, it by no means aims at emulating the assessment of individual member states based on more detailed investigations. At the same time, the approach may be useful to identify areas potentially affected by a certain concentration of a chemical, not necessarily taken into account during the monitoring.

The calculation will be extended to priority substances identified by Directive 2013/39/EU, including the list of 45 substances in Table 3. Moreover, the Commission Implementing Decision (EU) 2015/495 of 20 March 2015 establishes a "watch list" of additional substances (Table 4). These represent chemicals of potential concern at the European scale and will be included in the calculation as far as possible (depending on monitoring data availability).

CAS	**EU**	**Name**	**Priority hazardous subst.**	**Notes**
15972-60-8	240-110-8	Alachlor		*4 Only Tetra, Penta, Hexa and Heptabromodiphenylether (CAS-numbers 93703-48-1, 32534-81-9, 36483-60-0, 68928-80-3, respectively).* *5 Fluoranthene is on the list as an indicator of other, more dangerous polyaromatic hydrocarbons.* *6 Nonylphenol (CAS 25154-52-3, EU 246-672-0) including isomers 4-nonylphenol (CAS 104-40-5, EU*
120-12-7	204-371-1	Anthracene	X	
1912-24-9	217-617-8	Atrazine		
71-43-2	200-753-7	Benzene		
		Brominated diphenylethers	X[4]	

7440-43-9	231-152-8	Cadmium and its compounds	X
85535-84-8	287-476-5	Chloroalkanes, C10-13	X
470-90-6	207-432-0	Chlorfenvinphos	
2921-88-2	220-864-4	Chlorpyrifos(Chlorpyrifos-ethyl)	
107-06-2	203-458-1	1,2-dichloroethane	
75-09-2	200-838-9	Dichloromethane	
117-81-7	204-211-0	Di(2-ethylhexyl)phthalate (DEHP)	X
330-54-1	206-354-4	Diuron	
115-29-7	204-079-4	Endosulfan	X
206-44-0	205-912-4	Fluoranthene[5]	
118-74-1	204-273-9	Hexachlorobenzene	X
87-68-3	201-765-5	Hexachlorobutadiene	X
608-73-1	210-168-9	Hexachlorocyclohexane	X
34123-59-6	251-835-4	Isoproturon	
7439-92-1	231-100-4	Lead and its compounds	
7439-97-6	231-106-7	Mercury and its compounds	X
91-20-3	202-049-5	Naphthalene	
7440-02-0	231-111-4	Nickel and its compounds	
		Nonylphenols	X[6]
		Octylphenols[7]	
608-93-5	210-172-0	Pentachlorobenzene	X
87-86-5	201-778-6	Pentachlorophenol	
		(PAH)[8]	X
122-34-9	204-535-2	Simazine	
		Tributyltin compounds	X[9]
12002-48-1	234-413-4	Trichlorobenzenes	
67-66-3	200-663-8	Trichloromethane (chloroform)	
1582-09-8	216-428-8	Trifluralin	X
115-32-2	204-082-0	Dicofol	X
1763-23-1	217-179-8	(PFOS)	X
124495-18-7		Quinoxyfen	X
		(Dioxins/d.-like)	X[10]
74070-46-5	277-704-1	Aclonifen	
42576-02-3	255-894-7	Bifenox	
28159-98-0	248-872-3	Cybutryne	
52315-07-8	257-842-9	Cypermethrin[11]	
62-73-7	200-547-7	Dichlorvos	

203-199-4) and 4-nonylphenol (branched) (CAS 84852-15-3,

7 Octylphenol (CAS 1806-26-4, EU 217-302-5) including isomer 4-(1,1',3,3'-tetramethylbutyl)-phenol (CAS 140-66-9, EU 205-426-2).

8 Including benzo(a)pyrene (CAS 50-32-8, EU 200-028-5), benzo(b)fluoranthene (CAS 205-99-2, EU 205-911-9), benzo(g,h,i)perylene (CAS 191-24-2, EU 205-883-8), benzo(k)fluoranthene (CAS 207-08-9, EU 205-916-6), indeno(1,2,3-cd)pyrene (CAS 193-39-5, EU 205-893-2) and excluding anthracene, fluoranthene and naphthalene, which are listed separately.

9 Including tributyltin-cation (CAS 36643-28-4).

10 This includes the following compounds: 7 polychlorinated dibenzo-p-dioxins (PCDDs): 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8-H6CDD (CAS 39227-28-6), 1,2,3,6,7,8-H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9)

10 polychlorinated dibenzofurans (PCDFs): 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8-P5CDF (CAS 57117-41-6), 2,3,4,7,8-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918-21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0) 12 dioxin-like polychlorinated biphenyls (PCB-DL): 3,3’,4,4’-T4CB (PCB 77, CAS 32598-13-3), 3,3’,4’,5-T4CB (PCB 81, CAS 70362-50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS 65510-44-3), 3,3’,4,4’,5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5'-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3’,4,4’,5,5’-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5'-H7CB (PCB 189, CAS 39635-31-9).

11 This includes the eight isomers contributing to CAS 52315-07-8, and therefore also CAS 67375-30-8 (Alpha cypermethrin).

12 This includes 1,3,5,7,9,11-Hexabromocyclododecane (CAS 25637-99-4), 1,2,5,6,9,10-Hexabromocyclododecane (CAS 3194-55-6), α-

		Hexabromocyclododecanes(HBCDD)	X[12]	*Hexabromocyclododecane (CAS 134237-50-6), β-Hexabromocyclododecane (CAS 134237-51-7) and γ-Hexabromocyclododecane (CAS 134237-52-8).*
76-44-8/1024-57-3	200-962-3/213-831-0	Heptachlor and heptachlor epoxide	X	

Table 3 – Priority substances (Dir. 2013/39/EU) EU-number: European Inventory of Existing Commercial Substances (EINECS) or European List of Notified Chemical Substances (ELINCS).

CAS	**EU**	**Name**	
57-63-6	200-342-2	7-Alpha-ethinylestradiol (EE2)	*(1) Erythromycin (CAS number 114-07-8, EU number 204-040-1), Clarithromycin (CAS number 81103-11-9), Azithromycin (CAS number 83905-01-5, EU number 617-500-5).* *(2) Imidacloprid (CAS number 105827-78-9/138261-41-3, EU number 428-040-8), Thiacloprid (CAS number 111988-49-9), Thiamethoxam (CAS number 153719-23-4, EU number 428-650-4), Clothianidin (CAS number 210880-92-5, EU number 433-460-1), Acetamiprid (CAS number 135410-20-7/160430-64-8).*
50-28-2, 53-16-7	200-023-8	17-Beta-estradiol (E2), Estrone (E1)	
15307-86-5	239-348-5	Diclofenac	
128-37-0	204-881-4	2,6-Ditert-butyl-4-methylphenol	
5466-77-3	226-775-7	2-Ethylhexyl 4-methoxycinnamate	
		Macrolide antibiotics (1)	
2032-65-7	217-991-2	Methiocarb	
		Neonicotinoids (2)	
19666-30-9	243-215-7	Oxadiazon	
2303-17-5	218-962-7	Tri-allate	

Table 4 – chemical substances in the "watch list".

3.2.2 Spatial and temporal resolution

Indicators can be computed with a resolution limited by the available maps of emission patterns. However, the results should be presented with a minimum level of aggregation, as the analysis does not capture local details (contmainated sites, individual emissions) that may significantly affect concentrations at a point. In practice, the computed indicators will be aggregated for sub-catchments as in the GREEN model.

While in the case of nutrients we refer to a specific year in which emissions (point and diffuse) are known, in the case of chemicals the model reflects the load at the time of monitoring. Monitoring data can be quite scattered in time, and in order to assemble a representative set of sample points it may be necessary to consider together points sampled in different years and in different days of the year. This can be done insofar as we can assume that emissions are varying gradually from year to year, there are no drastic discontinuities in emissions, and emissions can be approximated to constant in time along the year. For instance, pesticides with a strong seasonality in application are a clear case of deviation from these assumptions, just like emissions from industrial activities that may be discontinued at a certain time.

These considerations suggest the inherent uncertainty in the assessment of chemicals compared to other variables. Whenever sample points used to estimate emission factors are not referred to the same year, the results must be interpreted as a representative yearly average concentration for the period covered by the samples. Under the assumption that loads are constant throughout the year, a concentration duration curve can be computed based on the flow duration curve.

3.2.3 Input

The model relies on assumed emission patterns (population, land use, livestock etc.). It critically depends on a dataset of measured loads of chemicals, used to infer emission factors for a given emission pattern. At present, the IPChem[11] platform exists that provides pan-European datasets of chemical monitoring results from different sources. The possibility to use monitoring data from member states directly is currently being explored.

3.2.4 Preliminary assessment

The approach is being applied in the context of the JRC support to the EU strategy for the Danube region, in collaboration with ICPDR. Pistocchi and Loos, 2009, estimate emission factors and map concentrations and loads of perfluorinated compounds (PFOS, PFOA) and Pistocchi et al., 2012, estimate emission factors and map concentrations and loads for a number of emerging polar contaminants in Europe. Figure 3 displays an example map of chemical loads of Naproxen estimated on the basis of observations.

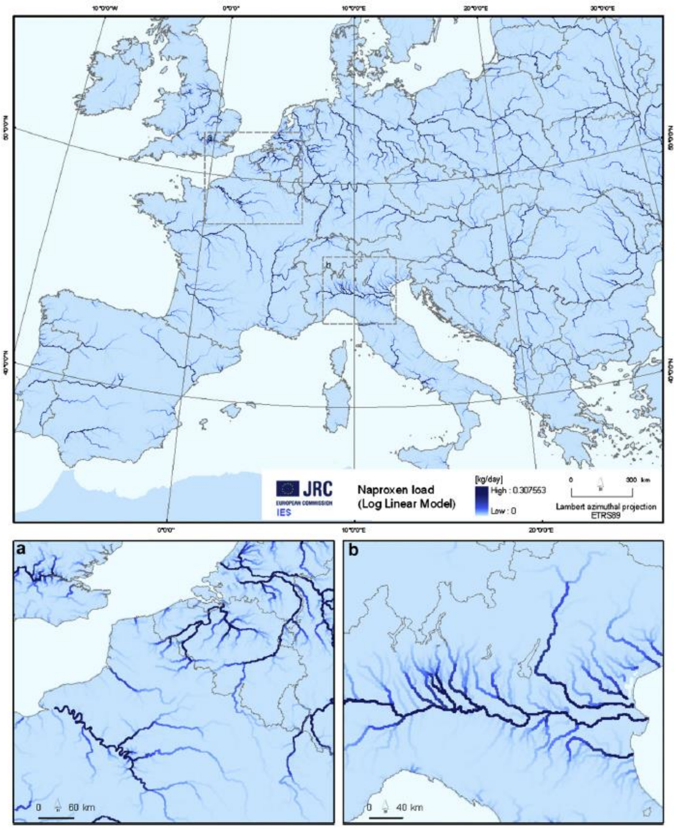

Figure 3 – example map of loads of a chemical (Pistocchi et al., 2012). Reproduced with permission from the publisher.

3.2.5 Previous applications

Perfluorinated compounds (Pistocchi and Loos, 2009); 16 polar chemicals including some of the priority substances (Pistocchi et al., 2012).

3.2.6 Strengths

Simplicity, transparency; by construction, good correspondence with observed concentrations.

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[11] https://ipchem.jrc.ec.europa.eu/RDSIdiscovery/ipchem/index.html

3.2.7 Weaknesses

Depends on data available; difficult to obtain robust estimates if data base is not sufficient. The method only addressed loads as measured (e.g. dissolved phase only, if loads are dissolved concentration times water discharge). Generalization to sediment-borne contaminants possible, but suffering from lack of reliable sediment flow estimates.

The method allows estimating loads when these are constant: strongly seasonal or unsteady emissions are not addressed correctly. Emission factors derived from observations do not reflect point emissions and specific cases (e.g. contaminated sites or accidents). In all those cases, the model serves as a screening tool valid only for orders-of-magnitude assessment. The accuracy of the model can be evaluated for each of the substances considered and the uncertainty of the indicators will be characterized when prepairng the respective maps, thus allowing to discard those chemicals for which the indicator cannot be considered reliable due to the above limitations.

3.2.8 State of play

Calculations for most priority substances and watch-list substances are underway. The sample point data used on purpose are those reported in IPChem. For some substances, data are rather limited and/or spanning a long sampling period in which the assumption of constant loads cannot be accepted. Additional data, including data reported under the WFD by member states, will be tested insofar as available. Monitoring for certain priority substances can be weaker, hence data availability may be limiting.

3.3 Oxygen-depleting substances (BOD) and suspended sediments

3.3.1 Methodology

The approach followed for nutrients and chemicals can be generalized to any constituent. In particular, the GREEN model will be generalized to BOD and total suspended sediments (TSS), hence GREEN+. BOD and TSS reflect similar conditions of uncertainty.

3.3.2 Spatial and temporal resolution

See § 3.1.2 and 3.2.2.

3.3.3 Input

Sources of sediments are assumed to follow the pattern of the JRC European soil erosion map[12].

Emissions of BOD can be estimated from information on point and diffuse sources of pollution as for GREEN. Observed sediment concentration and BOD data are needed to calibrate the model. The data available in the EEA's Waterbase[13] will be used as a starting point. More datasets, including data reported under the WFD by member states, will be tested insofar as available. For suspended sediments, data from the scientific literature collected by the JRC will be also used.

3.3.4 Preliminary assessment

None.

3.3.5 Previous applications

None.

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[12] http://esdac.jrc.ec.europa.eu/content/soil-erosion-water-rusle2015

[13] http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-10

3.3.6 Strengths

See § 3.1.6 and 3.2.6.

3.3.7 Weaknesses

See § 3.1.7 and 3.2.7.

3.3.8 State of play

Sediment and BOD model development is underway in the context of FP7 project Globaqua.

4. Flow regime

4.1 Methodology

The model used for hydrological assessments at the JRC is LISFLOOD. This is a full-blown spatially distributed hydrological model taking into account water abstractions in the water balance. With a hydrological model of this type, it is possible to compute several indicators of flow regime alteration, including water exploitation indexes and the number of days when flow is below a natural flow percentile, due to abstractions (see par. 4.4).

4.2 Spatial and temporal resolution

Model resolution is 5 km all over Europe, allowing in principle to describe every single water body with a catchment area of 25 km2 or more. The model works at daily time step.

4.3 Input

Along with the typical input of hydrological models (data on soils, land use, weather forcing, and water discharge data used for model calibration), the model relies on estimates of water abstractions. At present, these are derived from existing water demand datasets applied in the context of the impact assessment of the Blueprint to Safeguard Europe's Water resources (Communication from the Commission COM(2012)673)[14]. These datasets include:

- livestock

- industrial and energy sector

- household

- irrigation.

Demand is typically estimated by spatial disaggregation of the latest Eurostat-reported data, when available. The irrigation demand is estimated as simulated precipitation deficit using a crop growth model.

4.4 Preliminary assessment

LISFLOOD has been used to produce indicators of flow regime alteration (number of days in the year when discharges fall below the natural 10%-ile or 25%-ile), as well as the Water Exploitation Index (WEI+) for consumption and for abstractions, i.e.the ratio of consumed water (or abstracted water) to renewable water availability. Figure 4 shows examples of these indicators based on the model output version currently available[15]. The two indicators represent metrics of hydrological alteration, often used in the assessment of large regions when specific targets of environmental flow requirements are not defined.

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[14] http://ec.europa.eu/environment/water/blueprint/pdf/EUR25552EN_JRC_Blueprint_Optimisation_Study.pdf

[15] http://publications.jrc.ec.europa.eu/repository/handle/JRC96943

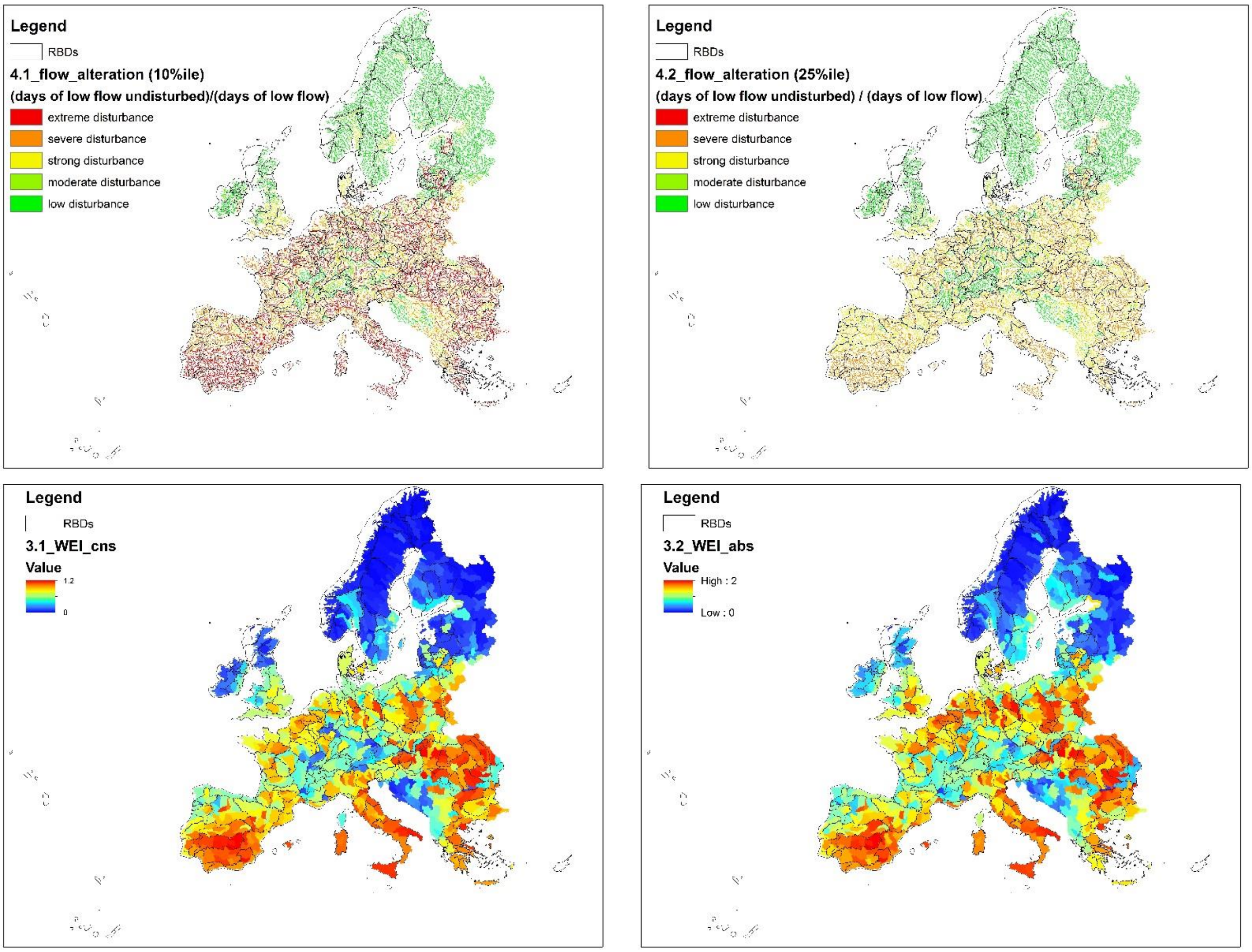

Figure 4 – above: flow regime alteration; below: WEI for consumption and abstractions, respectively.

4.5 Previous applications

LISFLOOD is extensively used for applications ranging from flood forecasting, to drought assessment, to climate change impact studies, to analysis of water resources. In particular, the model has been at the core of the impact assessment of the Blueprint to Safeguard Europe'swater resources.

In recent times, LISFLOOD output is being exploited for the European Water Accounts kept by the EEA.

4.6 Strengths

The model can be regarded as the most extensively calibrated operational pan-European flow discharge model, and has proved to perform satisfactorily across scales from the single catchment to continental or global level.

4.7 Weaknesses

The model allows a comprehensive representation of the terrestrial water cycle. However, particularly for the assessment of flow regime alterations due to abstractions, it depends directly on the representation of the latter. At present, water use and abstraction data in Europe are not commonly available and, when available, they are generally not distributed in space but aggregated by administrative units or basins. This limits the possibility of accurately describing the effects of these pressures.

4.8 State of play

The abovementioned flow alteration indicators are being re-computed with a new calibration of the LISFLOOD model completed in 2016, and will be checked on the basis of observed flow duration curves interpolated at European scale.

5. Hydromorphological alteration

5.1 Methodology

We propose to characterize hydromoprhological alterations through two types of indicators addressing:

- the level of naturalness or alteration of floodplains

- the presence of dams and other stream barriers.

The former include the % of floodplains under natural, agricultural or artificial land use, and the density of infrastructure in the floodplains.

The latter include the % of drainage area of a stream that is intercepted by dams, and the % of the stream length that is free from dams (or other stream barriers).

5.2 Spatial and temporal resolution

The indicators reflect land use, vegetation, infrastructure and dams at a given instant in time. This can be considered representative of some contiguous years.

The indicators used for pan-European assessment are proposed at a resolution of 1 km to balance detail and generality.

5.3 Input

Land cover is characterized by Corine (currently, version 2006 has been used pending full validation of version 2012).

Infrastructure is characterized using OpenStreetMap[16].

Floodplains are characterized on the basis of morphology and other land surface characteristics following Weissteiner et al., 2013.

5.4 Preliminary assessment

The above indicators have been evaluated for Europe in Pistocchi et al., 2015 (see Figure 5). The indicators related to dams and stream barriers are not considered reliable due to the lack of sufficient information.

5.5 Previous applications

None.

5.6 Strengths

Conceptual simplicity and robustness.

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[16] http://www.openstreetmap.org

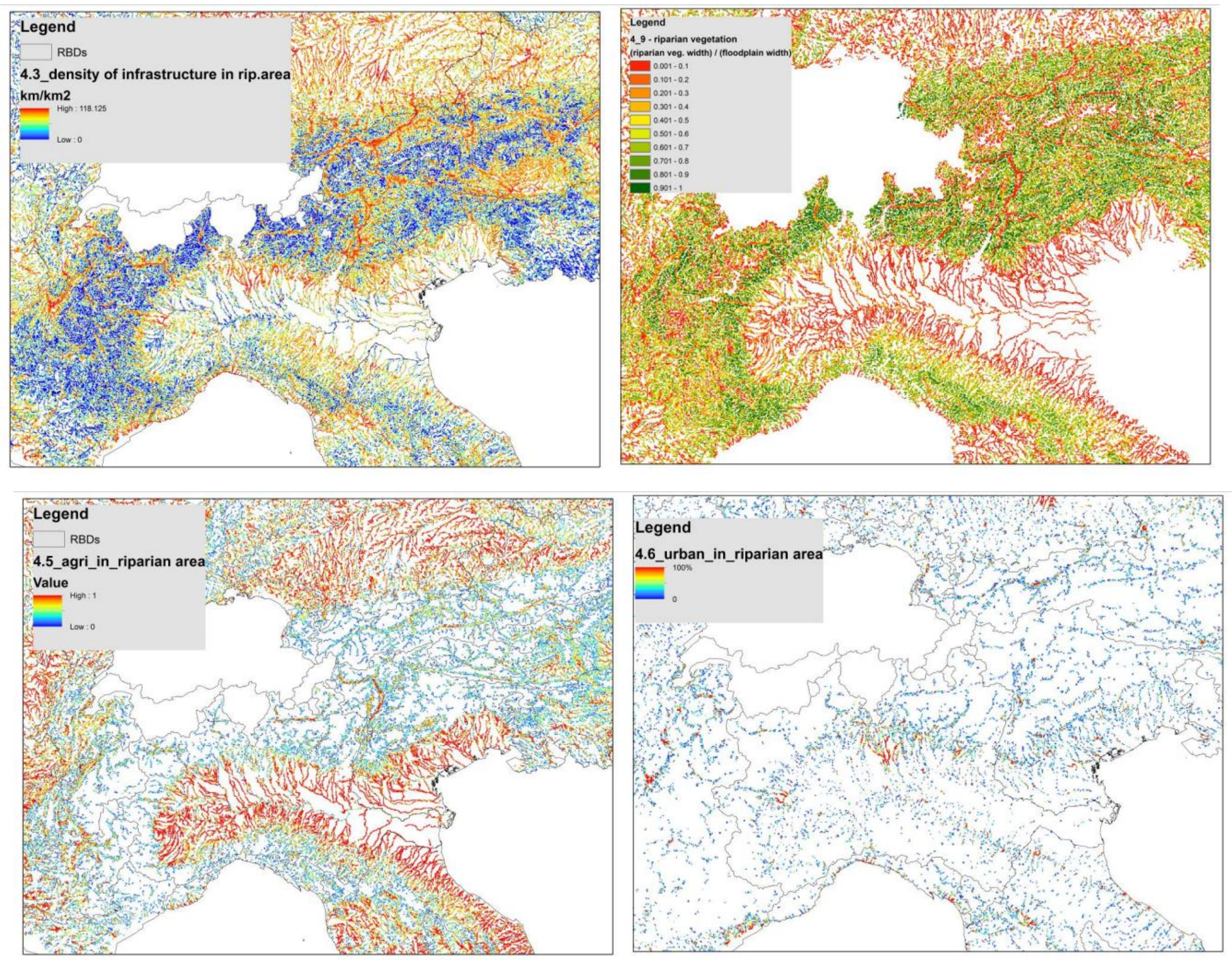

Figure 5 – example maps of hydromorphological alteration indicators.

5.7 Weaknesses

Not capturing hydromorphological processes explicitly, but only through proxies of complex phenomena. Dams and stream barriers insufficiently mapped at pan-European scale yet.

5.8 State of play

Improvements to the dams layer underway (also in the context of the AMBER H2020 project). Riparian indicators are updated using new Copernicus layers[17].

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[17] http://land.copernicus.eu/local/riparian-zones

6. Groundwater quality

6.1 Methodology

At European scale, we address the threat to groundwater quality represented by agriculture, as urban areas and contaminated sites are best addressed at a more local scale. We use the EPIC model[18] results regarding leaching of nitrogen to identify areas with higher downward fluxes of fertilizers. Although specific to fertilizers, this indicator is expected to be representative of any soluble chemical applied on agricultural soils, which may eventually percolate to aquifers. So, for instance, we expect that a similar indicator computed for certain pesticides would yield similar maps. Fertilizers, on the other hand, are chemicals for which application rates are much better known, and monitoring data are more abundant.

We selected the biophysical model EPIC because it simulates crop production under different farming practices and operations including fertilization and irrigation application rates and timing and because it considers nutrient losses to the environment (N leaching and runoff). In addition, it has been thoroughly evaluated and applied from local to continental scale (Gassman et al. 2005) and used in global assessments (Liu et al. 2007). Furthermore the model is already integrated in a GIS system working at European scale. For the EPIC run we will use the model-computed annual nitrate leaching below the root zone as an indicator of potential groundwater contamination.

6.2 Spatial and temporal resolution

While EPIC works at daily scale for Europe, we consider the annual leaching load. Model results are referred to a 5 km grid but will be aggregated at subbasin scale as for GREEN.

6.3 Input

A geodatabase was developed to support the application of EPIC for the entire continent. The geodatabase includes all the data required for EPIC modelling: meteorological daily data, soil profile data, crop distribution and management data, and scenario information. The landuse was defined using a map of 1 × 1 built from the combination of CAPRI (Britz, 2004), SAGE (Monfreda et al., 2008), HYDE 3 (Klein Goldewijk and Van Drecht, 2006) and GLC2006 databases.

6.4 Preliminary assessment

The above indicator has been evaluated for Europe as described in Pistocchi et al., 2015, and updated following correction of discrepancies highlighted by comments from member states (Figure 6). It is important to note that the EPIC model predicts value at field scale, and the simulated losses are to be considered as below the root zone, not taking into account other processes occurring in the unsaturated and saturated zones, in-stream processes and other factors (groundwater body depth and type, sub lateral flow, impermeable layers, etc.). In some situations the model has shown to underestimate leaching concentrations and loads while overestimating runoff. For this reason, one might think of the total load predicted by EPIC (leaching and runoff) and the concentration in both leaching and runoff water losses as more representative indicators. The indicator, although conceptually well-founded and based on the best available information to parameterize the EPIC model at European scale, requires further refinement to reflect specific conditions, and/or more context-dependent interpretation.

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[18] http://epicapex.tamu.edu/epic/

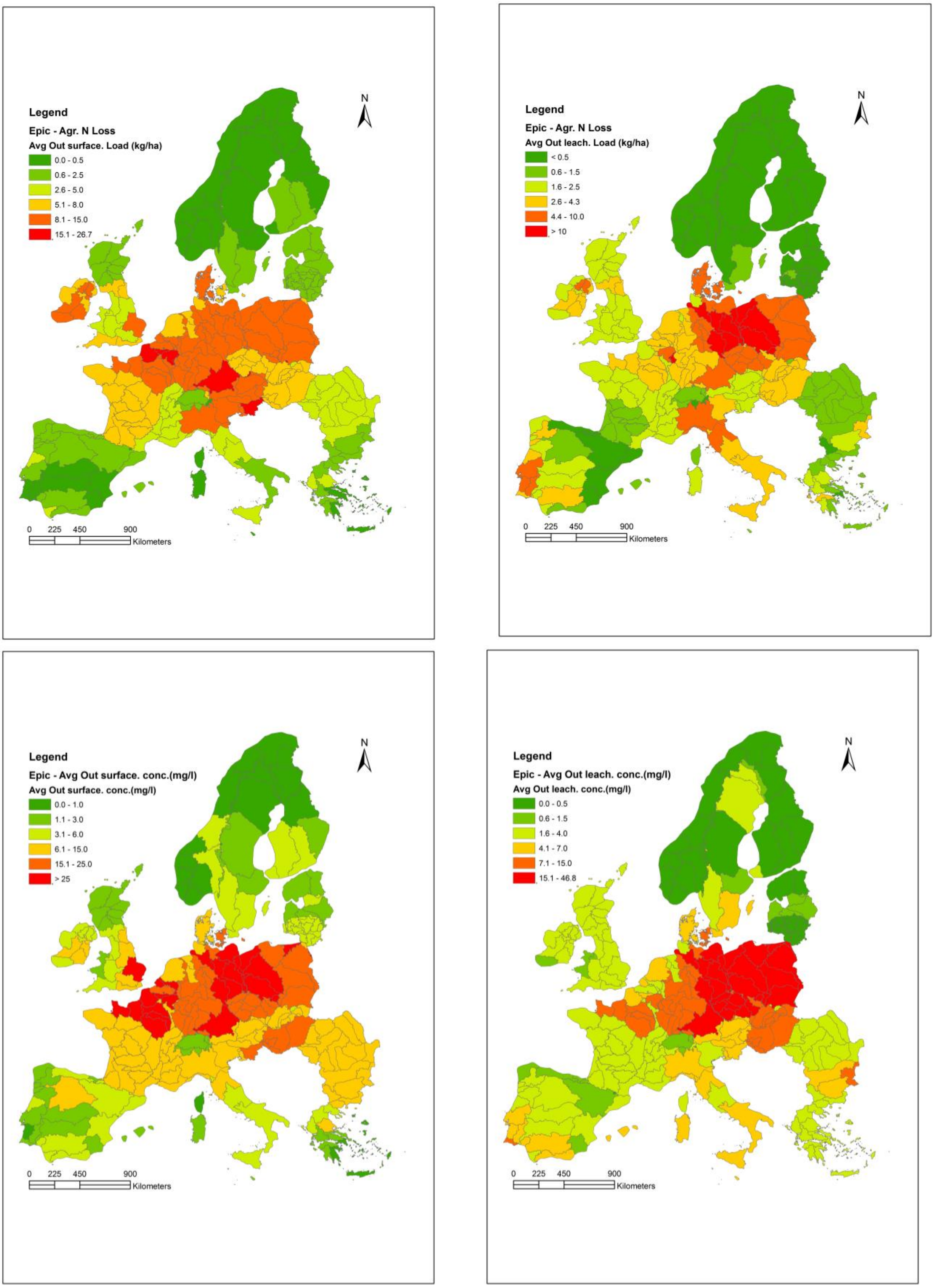

Figure 6 – nitrogen loads (above) and concentrations (below) from agricultural diffuse sources, as modelled by EPIC (average by RBD).

6.5 Previous applications

The model has been used to assess different scenarios in the context of the implementation of the Nitrates Directive by Member States. In particular the following scenarios were tested:

- Optimal mineral fertilization
- Introduction of a catch crop
- Evaluation of the closed fertilization periods by comparing actual closed periods
- Evaluation of the derogation on nitrate leaching

6.6 Strengths

Physically based, and sensitive to farming practices (in particular timing, type and intensity of fertilization).

6.7 Weaknesses

Parameterization is data intensive and may be limited by lack of data making model predictions incapable to reflect specific local situations. The proxy of leaching fluxes does not account for dilution in the aquifer and further contaminant attenuation below the root zone.

6.8 State of play

Improvements have been made to better consider the denitrification process and N_2O emission to the atmosphere.

7. Groundwater quantitative status

7.1 State of play

The LISFLOOD model has been recently upgraded to incorporate a better description of the groundwater component of the water cycle. On the basis of this development, indicators for groundwater quantitative status (essentially, the balance between groundwater recharge and abstractions) are under evaluation. The possibility to compute a reasonable indicator of groundwater quantitative status depends on the availability of robust estimates of groundwater recharge (stemming from the LISFLOOD model within the limits of its calibration) as well as on the possibility to obtain European-scale estimates of the abstractions from groundwater, presently limited by the available Eurostat-reported data.

8. Urban runoff and combined sewer overflows

8.1 State of play

The LISFLOOD model computes urban runoff as rainfall on urban areas diminished of evaporation and soil infiltration, on a daily basis. Total annual urban runoff may be regarded as a proxy for total annual load of contaminants from urban diffuse sources including the wash-out of roof and road surfaces, where contaminants accumulate during dry weather due to atmospheric deposition and emissions from traffic and other human activities.

Another urban source of pollution is represented by combined sewer overflows (CSOs). Typically, CSOs occur in relatively large urban areas where, during rainfall events, stormwater discharge exceeds a multiple of dry weather ("black") discharge, so that sewers are unable to convey the total combined discharge. Combined sewers are typically designed to convey between 2 and 10 times the black discharge; beyond these thresholds, dilution was assumed in the past to be sufficient to allow the release of excess flow directly to receiving water bodies.

A CSO indicator is being developed that consists of computing the sum of daily runoff volumes, for each urban area, in excess of a multiple (between 1 and 10) of "black" discharge, estimated on the basis of the area's population. This is expected to represent a proxy of the actual CSO load.

As urban storms usually develop over a time scale of hours, while LISFLOOD works with daily precipitation, the thresholds of the ratio between runoff volume and "black" water discharge need to be calibrated against evidence of functioning of CSOs.

Both the total urban runoff and the CSO indicator represent loads of contaminants and can be interpreted in terms of concentrations taking into account the diluting discharge of the receiving water body.

9. Other pressure indicators

9.1 State of play

9.1.1 Alien species

The JRC maintains a European Alien Species Information Network (EASIN[19]) that brings together information on alien species in Europe. This provides a basis for the development of possible indicators of ecological pressure from alien species on water bodies. Such indicators are still being explored.

9.1.2 Plastic litter

Plastic litter is addressed in the context of the Marine Strategy Framework Directory. The JRC has started an exploratory project (RIMMEL[20]) on the characterization of plastic litter loads from rivers. The project will try to quantify floating macro-litter loads through rivers to marine waters, by collecting existing data, developing a European observation network, deploying a camera system and using the resulting data to build a statistical inverse model of litter loading based on the characteristics (flows, population, economic factors) of the catchments upstream of the observation points. This would be the first-ever European scale quantification of loads of floating litter to the European seas. As ongoing work, anyway, the assessment of this pressure is not likely to be established well enough in order to be used in the assessment of the 2nd RBMPs.

9.1.3 Aggregated pressures in coastal and transitional waters

Coastal and transitional waters often suffer from a combination of pollution, morphological and management pressures that are difficult to disentangle. A combined indicator ("Land use simplified index" - LUSI) has been proposed in the past (see Pistocchi et al., 2015) to represent this combination of pressures. This indicator requires further discussion and testing.

References

1. Amparore, A. 2012. Development of a spatially explicit census of point sources and scattered dwelling emissions for continental Europe. JRC Water Resource Unit report 7/25/2012
2. Bouraoui F, Grizzetti, B Aloe A. 2011. Long term nutrient loads entering European seas. JRC Technical reports EUR24726
3. Bouraoui F., Grizzetti B., Aloe A., 2009. Nutrient discharge from rivers to seas for year 2000. JRC Report EUR 24002 EN. ISBN 978-92-79-13577-4. pp.72.
4. Bouraoui, F., Thieu, V., Grizzetti, B., Britz, W., Bidoglio, G., 2014. Scenario analysis for nutrient emission reduction in the European inland waters. Environmental Research Letters 9.
5. Dubber, D., gray, N.F. 2010. Replacement of chemical oxygen demand (COD) with total organic carbon (TOC) for monitoring wastewater treatment performance to minimize disposal of toxic

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[19] https://easin.jrc.ec.europa.eu/

[20] http://mcc.jrc.ec.europa.eu/dev.py?N=simple&O=380&titre_chap=%C2%A0&titre_page=RIMMEL . See also Hanke, G. Gonzalez, D.; Riverine Litter – JRC Tools for Quantification – RIMMEL project summary report; JRC105137, upcoming.

analytical waste. Journal of Environmental Science and Health, Part A -Toxic/Hazardous Substances and Environmental Engineering 45, 1595-1600. http://dx.doi.org/10.1080/10934529.2010.506116

6. EEA. 2016a. Waterbase - UWWTD: Urban Waste Water Treatment Directive – reported data. http://www.eea.europa.eu/data-and-maps/data/waterbase-uwwtd-urban-waste-water-treatment-directive-4
7. EEA. 2016b. The European Pollutant Release and Transfer Register (E-PRTR), Member States reporting under Article 7 of Regulation (EC) No 166/2006. http://www.eea.europa.eu/data-and-maps/data/member-states-reporting-art-7-under-the-european-pollutant-release-and-transfer-register-e-prtr-regulation-12
8. European Commission, 2007. SEC(2007) 339. Commission Staff working document accompanying document to the Report from the Commission to the Council and the European Parliament on the implementation of the Council Directive 91/676/EEC concerning the protection of the waters against pollution caused by nitrates from agricultural sources for the period 2000-2003. COM(2007)120.
9. European Environment Agency, 2010. Report on the Status of Environment (SOER) 2010. Thematic Assessment Freshwater Quality.
10. EUROSTAT. 2016. The Environment Water database. http://ec.europa.eu/eurostat/web/environment/water/database [accessed 16.10.2016]
11. Freire, S., Pesaresi, M. 2015. GHS population grid, derived from GPW4, multitemporal (1975, 1990, 2000, 2015). European Commission, Joint Research Centre (JRC). PID: http://data.europa.eu/89h/jrc-ghsl-ghs_pop_gpw4_globe_r2015a
12. Grizzetti B., Bouraoui F., Billen G., van Grinsven H., Cardoso A.C., Thieu V., Garnier J., Curtis C., Howarth R., Jones P., 2011. Nitrogen as a threat to European water quality. In The European Nitrogen Assessment, Sutton M., Britton C., Erisman J.W., Billen G., Bleeker A., Greenfelt P., van Grinsven H., Grizzetti B., (eds), Cambridge University Press.
13. Grizzetti, B., Bouraoui, F., Aloe, A., 2012. Changes of nitrogen and phosphorus loads to European seas. Global Change Biology 18, 769-782.
14. Grizzetti, B., Passy, P., Billen, G., Bouraoui, F., Garnier, J., Lassaletta, L., 2015. The role of water nitrogen retention in integrated nutrient management: Assessment in a large basin using different modelling approaches. Environmental Research Letters 10.
15. Jönsonn, H., Vinnerås, B. 2003. Adapting the nutrient content of urine and faeces in different countries using FAO and Swedish data. 2nd international symposium on ecological sanitation. April 2003.
16. La Notte, A., Liquete, C., Grizzetti, B., Maes, J., Egoh, B., Paracchini, M., 2015. An ecological-economic approach to the valuation of ecosystem services to support biodiversity policy. A case study for nitrogen retention by Mediterranean rivers and lakes. Ecological Indicators 48, 292-302.
17. Leip, A., Billen, G., Garnier, J., Grizzetti, B., Lassaletta, L., Reis, S., Simpson, D., Sutton, M.A., De Vries, W., Weiss, F., Westhoek, H., 2015. Impacts of European livestock production: Nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity. Environmental Research Letters 10.
18. Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B., Zulian, G., 2015. Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. Environmental Science and Policy 54, 268-280.
19. Malagó A., Venhor M., Gericke A., Vigiak O., Bouraoui F., Grizzetti B., Kovacs A., 2015. Modelling nutrient pollution in the Danube River Basin: a comparative study of SWAT, MONERIS and GREEN models. JRC Report EUR 27676. Publications Office of the European Union. Luxembourg.
20. Morée, A.L., Beusen, A.H.W., Bouwman, A.F., Willems, W.J. 2013. Exploring global nitrogen and phosphorus flows in urban wastes during the twentieth century. Global Biogeochemical cycles 27, 836-846, doi: 10.1002/gbc.20072 & supporting information
21. Nelson, Murray. 2008. Sanitation for unserved populations: technologies, implementation challenges, and opportunities. Annu. Rev. environ. Resourc. 33, 119-151. doi: 10.1146/annurev.environ.33.022007.145142

22. Pistocchi A., Aloe A., Bizzi S., Bouraoui F., Burek P., de Roo A., Grizzetti B., van de Bund W., Liquete C., Pastori M., Salas F., Stips A., Weissteiner . C., Bidoglio G., 2015. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures.Part I – Pan-European scale screening of the pressures addressed by member states. JRC Report EUR 27465 EN ISBN:978-92-79-51888-1. Luxembourg: Publications Office of the European Union. 88 pp.
23. Pistocchi, A., GIS Based Chemical Fate Modeling: Principles and Applications. Wiley, Hoboken, April 2014, ISBN: 978-1-1180-5997-5, 520 pp
24. Pistocchi, A., Loos, R., A Map of European Emissions and Concentrations of PFOS and PFOA, Environmental Science & Technology 2009 43 (24), 9237-9244
25. Pistocchi, A., Marinov, D., Gawlik, B., Pontes, S., Continental Scale Inverse Modeling of Common Organic Water Contaminants in European Rivers. Environmental Pollution, Volume 162, March 2012, Pages 159-167. http://dx.doi.org/10.1016/j.envpol.2011.10.031
26. Powley, Dürr, Lima, Krom, van Cappellen. 2016. Direct discharges of domestic wastewater re a major source of phosphorus and nitrogen to the Mediterranean Sea. Environmental Science and Technology 50, 8722-8730, doi: 10.1021/act.est.6b01742 & supporting information
27. UN. 2011. Environmental Indicators. Inland water Resources. Wastewater. http://unstats.un.org/unsd/environment/wastewater.htm [accessed 16.10.2016]
28. Weissteiner C. J., Bouraoui F., Aloe A.: Reduction of nitrogen and phosphorus loads to European rivers by riparian buffer zones. Knowledge and Management of Aquatic Ecosystems, 408, 08, 2013. DOI: 10.1051/kmae/2013044

Annex 1 - Summary of outcomes of the workshop "Assessment of pressures on European water bodies"[21]

11-12 May 2016, European Commission DG Joint Research Centre (JRC) Ispra, Italy

1. Background of the workshop

The Commission (DG JRC) is using in-house models and other information to build indicators of pressures on water bodies, in the context of the 2nd river basin management plan (RBMP) implementation assessment (art. 18) and review of the WFD (art. 19). These indicators are meant to provide a picture of major water pressures at the European scale. The Commission's DG ENV encourages Member States (MS) to provide feedback to DG JRC on the indicators and the underpinning models, so that the European scale picture of water pressures they provide can be improved to a sufficient level of realism and representativeness, and can be consequently used as a basis for European water policy evaluation and development.

Moreover, DG ENV is steering the development of an integrated hydro-economic modelling platform in support to the evaluation of policies, with the broadest possible involvement of MS, and collaborates with DG JRC by leading a large study on the economics of water in Europe also in order to supplement JRC's biophysical models and indicators with additional economic evidence about the costs and benefits of reducing pressures and improving the conditions of freshwater and marine ecosystems.

JRC organised a workshop in Ispra on 11-12 May 2016 with the aim to collect feedback from MS experts on the proposed methodologies and indicators. This document summarises the outcome of this workshop

2. Main points of the presentations and related discussion

The workshop hosted presentations by the Commission's DG JRC on the models and indicators under preparation. These include indicators considered well established and applicable for the assessment; indicators requiring developments before application; and indicators still in a research phase and not applicable in the short term.

2.1 Flow regime alteration

Indicators of the alteration of hydrological regime, computed with the LISFLOOD model, include:

- the Water Exploitation Index (WEI+), or ratio of consumptive use of water on total freshwater availability;

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[21] The text of this annex has been submitted for comments to the workshop participants. Until now, we have received comments (not necessarily related to the text, but mainly addressing issues on the use of the JRC indicators) from participants from Romania and Sweden. their comments will be taken in due account when making use of the indicators.

- the number of days discharges are below a natural low flow threshold (the 10th percentile of “naturalized” flows[22]).

Both indicators aim at picturing the alteration of flow regime, and not its ecological impact. The discussion has highlighted that, in the computation of flow regime alteration indicators, the hydrological model of stream flow may be quite accurate for sufficiently large river catchments, while the most critical aspect is a lack of detailed information on water abstractions and regulation by dams. As a consequence, the simulation of hydrological processes cannot reflect site-specific features given the level of aggregation of the input data.

The indicators may reflect changes in water abstraction or consumption caused by measures such as improving water use efficiency or limiting withdrawals.

2.2 Nutrients in surface waters

Indicators of nutrient pollution, computed with the GREEN model, include concentrations of total nitrogen (N) and total phosphorus (P) in rivers and lakes.

The GREEN model predicts yearly N and P loads using the point (discharges from Waste Water Treatment Plants, WWTPs) and diffuse (agriculture, atmospheric deposition, scattered dwellings) emissions represented in inventories used as input. The model has been calibrated and provides satisfactory results, confirmed also during a recent benchmarking exercise with MONERIS and SWAT models in the Danube basin[23]. However, the discussion has highlighted that an update, including regional-targeted calibration, is needed. For point emissions, it is important that updated reported data from the MS are taken into consideration (data from the reporting of the Urban Waste Water Directive as made available by the EEA). For diffuse emissions, the model relies on fertilizer estimates from the CAPRI model. GREEN can only reflect the loads (and concentrations) represented in the data used for calibration. This means the model cannot reflect specific situations (e.g. high intensity loads during floods) if the corresponding sampling is not included in the datasets.

GREEN can be used to predict the effects of changes in point and diffuse emissions in the river basin associated to measures, such as changes in WWTPs or improved management of agricultural fertilizers.

2.3 Morphological alteration

Morphological alterations are strongly influenced by land use and the presence of infrastructure in floodplains. Another major pressure affecting river continuity and hydromorphological alteration is the presence of dams and other stream barriers.

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[22] “Naturalized” flows are flows simulated by the JRC LISFLOOD model, assuming no abstraction and absence of artificially regulated reservoirs. Depending on the intensity of abstractions and reservoirs regulation, low flows may occur for more days than expected under natural conditions. Flows should be under the natural 10th percentile for 10% of the year, or 36.5 days. The more days we have under this threshold, the more severe the alteration.

[23] Malagó A., Venhor M., Gericke A., Vigiak O., Bouraoui F., Grizzetti B., Kovacs A., 2015. Modelling nutrient pollution in the Danube River Basin: a comparative study of SWAT, MONERIS and GREEN models. JRC Report EUR 27676. Publications Office of the European Union. Luxembourg.

The JRC proposes two types of descriptive indicators:

- the percentage of urban and agricultural land use, the vegetation cover and the density of infrastructure in the floodplains
- the percentage of the catchment area at each river section that is intercepted by dams.

An additional indicator proposed by the JRC, reflecting the fragmentation of the stream network due to barriers (such as weirs, locks and dams), requires additional testing before it can be considered.

The urban and agricultural land use in floodplains, vegetation cover and density of infrastructure in the floodplains is represented in the available land cover maps or vegetation maps and (for many European regions) in OpenStreetMap. The distribution of dams can be mapped at European scale by combining different data sources such as GRanD, the Euro-Regional map, the DAMPOS dataset of the EEA and OpenStreetMap.

The discussion has highlighted that both land cover/infrastructure in the floodplains, and the dams indicators do not rely on model calculations and are therefore not subject to uncertainties associated with modelling. However, the reliability of the indicators obviously depends on the accuracy of input datasets. For dams, the best EU level dataset currently available is the one used by the European Environmental Agency, but is known to be incomplete and lacking consistency. As a result, initial pressure assessments have to be considered provisional at this stage. However, the Horizon2020 project AMBER will establish a more consistent and complete dataset in the next two years, which can be used to update the JRC indicators.

At regional scale, better data is known to be available. For the Danube river basin, the ICPDR has conducted a thoroughly assessment of the barriers that prevent fish migration, alteration of riparian areas and floodplains, and hydropeaking. These and similar data available for selected regions may be used to test the relevance and robustness of the proposed JRC indicators.

The discussion has also pointed to the fact that, in the case of morphological alterations, a process model describing the sediment balance and the consequent evolution of rivers would be useful but is presently not under development at the European scale. The proposed indicators can be used for a screening exercise, but cannot replace the assessment done by MS at the local scale, to detect the local ecological effects.

At the same time, a more detailed morphological characterization of rivers at European scale would be desirable. The JRC is testing the extension of remote sensing based methodologies developed in the context of the REFORM FP7 project to the pan-European scale, limited to the larger rivers (drainage area > 5,000 or 10,000 km2) that can be described with imagery coarser than used at more detailed scales. The potential use of this and other hydromorphology related indicators can be considered in future harmonization work in the context of the CIS hydromorphology group.

2.4 Chemicals in surface waters

The proposed indicators of chemical pollution pressures are the concentrations of selected substances, compared to the respective environmental quality standards (EQS). Concentrations are computed through a generalization of the GREEN model. Unlike for nutrients, emissions are not assumed to be known in the form of inventories, but estimated with the "riverine load method" described in the CIS Guidance Document n. 28. The method can be applied at

European scale provided a consistent dataset of observed riverine loads of chemicals is available. The JRC has started developing estimates for the current list of WFD priority substances using IPChem data on observed concentrations. More substances could be included in the future, e.g. selected river basin-specific chemicals or contaminants of emerging concern[24]. Other data sources for observed loads can be considered as well. Loads are computed from observed concentrations and simultaneously observed water flow; water flow estimations from the calibrated LISFLOOD model can be used when no flow observation is available.

The approach is data driven. Unlike knowledge-driven approaches such as the WEISS model presented at the workshop by Guy Engelen (VITO, Belgium), the riverine load method assumes a known emission pattern on which to perform the apportionment of the observed load. WEISS uses a detailed inventory of the emission sources, and applies emission factors derived from the literature. The WEISS and similar approaches can be used when emission sources are known with sufficient detail, while they are not applicable at European scale in the absence of such detailed information. Compared to the riverine load method, the GREEN model applied for nutrients may be regarded as an intermediate approach, sharing with WEISS the use of an inventory of emissions, but relying on observed loads for a specific calibration of model parameters representing processes (river and basin retention) not addressed in WEISS.

The discussion has clarified that, all in all, the maps to be produced on chemical concentrations of selected substances should be regarded as a screening level estimate, always to be confirmed by more specific assessments. The computed concentrations can never capture the exact concentration locally. Nevertheless, they are expected to allow identification of continental spatial patterns, and the range of concentrations predicted by this approach is expected to be well in line with observed concentrations.

A critical aspect is the comparison of predicted concentrations with EQS. This is needed in order to appropriately scale the quantities to reflect the associated risks. However, this should never be presented as a predicted breach of EQS in a specific river, due to the limitations of the approach, and particular care should be taken in the communication of the results.

Calculations until now have been limited to organic chemicals. For metals, it has been shown how it would be necessary to consider the natural background. This aspect will need to be further investigated before computing any emission factor with a riverine load method.

The data used for the apportionment of loads would also need a quality check procedure. Presently, IPChem data will be used in their original form but the results may help also identifying issues with the data.

Also, the discussion has suggested that JRC indicators on chemicals should be compared with the insights gained from other scientific projects including, in particular, FP7 project "Solutions".

2.5 Urban runoff and combined sewer overflows

It is now broadly acknowledged that urban runoff can have quite high concentrations of contaminants due to the wash-out of polluted surfaces and urban atmospheric deposition.

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[24] It has been suggested that a set of 5-10 chemicals might be able to explain most of the pollution issues in European river basins; if this proves true, in the future it might be decided to limit the indicators to that list of "top 10" or "top5" chemicals.

Urban runoff is computed in LISFLOOD as a fraction of the precipitation falling on urban land minus local evaporation and infiltration. Its ratio to the total discharge in the receiving water bodies can be regarded as a first order approximation of urban runoff pollution. The calculation of this indicator can reflect measures taken to limit urban runoff, e.g. by increasing infiltration and/or evapotranspiration (green roofs, parks etc.).

Combined sewer overflows may represent a significant source of pollution for certain water bodies. The indicator proposed by the JRC is the cumulative volume of daily urban runoff that exceeds a threshold related to the dry weather discharge daily conveyed by combined sewers. The latter depends on the population served by the sewers, while the thresholds need to be calibrated. A demonstrational calculation of the indicator, as presented at the workshop, needs to be considered experimental. Further research is needed before producing a usable indicator for this pressure.

2.6 Groundwater pollution and quantitative status

Nitrogen losses from agricultural land computed with the EPIC model are used as an indicator of the potential nitrogen contamination of groundwater. This should be interpreted with care, as it does not reflect nitrogen concentrations in groundwater, but only the upper extreme of loads potentially reaching groundwater, and from agricultural sources only.

EPIC was parameterized for Europe in the past years and provided realistic results favourably comparing with crop yield data. The estimation of agricultural nitrogen losses remains a challenge and data to calibrate the model specifically on these remain practically unavailable. The EPIC model results will be only updated at a later stage, and in the short term the indicator should be regarded as provisional and particularly subject to scrutiny.

Indicators of groundwater quantitative status may be in principle drawn from LISFLOOD model simulations. The model includes groundwater reservoirs identified on the basis of the aquifer zones represented in the 1:1,500,000 Hydrogeological map of Europe produced by EuroGeoSurveys. The residence time of these reservoirs is a model parameter automatically calibrated on the basis of the available observed river hydrographs. Groundwater abstractions are assigned to aquifers on the basis of country-level information on the share of groundwater in water supplies provided by Eurostat. The model computes a balance of the groundwater reservoirs and may in principle identify trends in groundwater depletion. It is apparent that the dynamics of groundwater are controlled by very local factors, and large-scale models can only predict general trends. At present, indicators of groundwater depletion computed by LISFLOOD must be regarded as experimental and needing further tests. In particular, a reliable representation of the distribution of groundwater abstractions is a fundamental ingredient. Many studies are conducted in the individual MS on groundwater, and a more effective dissemination of this knowledge would be extremely beneficial. Marco Petitta (La Sapienza University, Italy) gave information on the research project KINDRA (Horizon 2020) he coordinates. This is one opportunity to enhance such dissemination.

2.7 Intended use of the JRC indicators

The main reason for the Commission to develop a set of independent pressure indicators is the need to evaluate and monitor the effectiveness of the EU water policies at the European scale. If the indicators are realistic, the models used for their computation can be used also as tools to simulate scenarios with changing pressures, as a result of policies or other drivers (such as climate changes, implementation of measures or EU sectorial policies).

Another question is whether the pressures are evaluated consistently throughout the European Union. JRC indicators could be used to benchmark pressure and status reported by the Member States at a different scale. In fact, if JRC indicators are sufficiently reliable, it is expected that overall trends will be consistent with the pressures reported by the Member States. At the same time, JRC indicators do not take into account local conditions in specific water bodies, and should not be compared to reported pressures and status at water body level.

The aim of a benchmarking exercise is to understand the reasons for assessment discrepancies, and not judgmental. For instance, if a given river basin is flagged by Member State reports to suffer from a given pressure, but this is not found in the JRC pressure indicators, the knowledge available at the Commission is likely inadequate for that river basin.

The JRC pressure indicators are in progress, as new knowledge is available at the European level, including from new reports by the Member States. The benchmarking process with reported pressures/status in itself could prompt the Commission to seek an explanation for the discrepancies, and eventually to update the indicators. The overall goal is to have a coherent and shared vision of pressures at the European and river basin districts. This does not entail complete accordance between national and EU assessments, considering the data and resolution at which they are developed, rather a consistent picture.

3. Outcomes of the groups discussion

The workshop has discussed two broad aspects: the process in which the Commission is supposed to use the JRC pressure indicators, and the nature of the individual indicators. The following questions were posed:

On the process:

- What are the risks of using the EU indicators of pressures?
- What are the benefits of using the EU indicators of pressures?
- What scale is best to address the comparison?

On the indicators:

- Can the proposed indicators of pressures be useful in the assessment of the RBMPs? Why?
- What are the knowledge gaps?

The discussion has been organized in two working groups: one focussing on water quality aspects, and the other on hydrological/morphological alteration. The main points emerged in the discussion are summarized hereafter, for the two groups together.

3.1 What are the risks of using the EU indicators of pressures?

One main perceived risk is that if JRC indicators are applied at specific river basin district (RBD), river basin or water bodies, they may give an **inconsistent message** compared to the assessment done by the Member States. Consistency of the message about the conditions of waters is an important issue. To avoid this risk, European-scale assessments should be restricted to large-scale assessments, addressing the broad picture, without contradicting the messages from the finer-scale assessments conducted by the Member States. Possible consequences of inconsistent messages include:

- Possibility that certain stakeholders abuse the European scale assessment to support arguments against Member State assessments;
- A distorted picture due to different scales may be counterproductive and misleading for political discussions;
- Possibility that inconsistencies are interpreted as due to “bad reporting” or “bad implementation”, by stakeholders as well as by other services of the Commission: inconsistencies should not be seen per se as evidence of non-compliance.

Some experts suggested the most difficult case to handle in the political debate at Member States’ level is if discrepancies emerge between the European and the Member States’ scale of assessment, in which the latter highlights a problem that is not detected at European scale. For instance, Austria was assessing hydromorphological pressures (finding reasons to plan specific measures), only apparent in smaller streams not adequately represented by European scale analyses.

Miscommunication due to inconsistent messages may increase the burden of the Member States needing to clarify the situation vis-à-vis requests from the public, stakeholders and the Commission.

The risk of miscommunication should be minimized through careful choice of the wording for the definition of the indicators, the choice of the presentation format of maps and statistics of the indicators, legends in figures etc.

One aspect extensively pointed out during the discussion is that indicators quantify the intensity of **pressures, without considering the impact on the status**. This cannot be directly compared to significant pressures as they are reported by the Member States – the significance of a pressure depends on local conditions including water body type. Related to this is the fact that the JRC pressure indicators do not account for the presence of mitigating measures (e.g. fish passes at dams). The JRC pressure indicators are limited to selected aspects of water quality, hydrological regime and morphological alterations not necessarily representing the full range of pressures.

Certain indicators may be **misleading**. For instance, in the case of nutrients, concentrations per se do not represent pressures unless they exceed certain thresholds. Therefore considering pressures to be represented directly by concentrations and not by concentration threshold exceedances may lead to wrong conclusions in some cases. This can be improved upon by comparing modelled nutrient concentrations with nutrient standards corresponding to the good-moderate status boundary.

Overlooking some local problems or overestimation of given pressures locally are practically unavoidable in European scale assessments. In general, the interpretation of the indicators should be considerate of the assumptions made with the JRC models. It should be careful not to come to conclusions beyond the limitations of the modelling framework. The coarse scale of modelling and the limitations in the input data make the results not interpretable at face value (e.g. a high modelled concentration should not be seen automatically as an indication of non-compliance with an EQS, but only as an indication that, in some cases, there might be an exceedance of EQS). The interpretation of model results should be always backed by local information as reported by the Member States.

3.2 What are the benefits of using the EU indicators of pressures?

The JRC models and indicators, although coarser than models used for local assessments, can still **provide support** on some aspects for Member States countries not (yet) in the condition to perform their own country-level assessments. This could be the case when a **non-unique methodology** is adopted across the country by the individual RBD competent authorities, and when Member States cannot allocate resources for country-wide assessments.

A European picture of the pressures, drawn from a homogeneous and consistent approach, can be also useful in the **prioritisation of funding**. EU-level assessment may help Member States' planning to focus where to best spend the available funds for measures.

The JRC pressure indicators may provide a **broad picture at the European scale** with enhanced transparency thanks to the use of an **independent methodology**, and may consequently support EU policy. All Member States are assessed in the same way, and there is also a possibility to make analyses across sectors.

The indicators may be regarded as **scoping tool** giving a first impression of hotspots of pressures, so to identify where to look closer.

Model-based indicators can be used to run **scenarios** of future pressures **at the European scale**.

Another important benefit of the indicators could be in their capacity, once appropriately validated, to **track the progress** in the implementation of measures to reduce pressures. For this, it is important that indicators reflect the measures implemented by the member states, which is possible for the case of nutrients and hydrological alteration indicators but not for, e.g., morphological alteration indicators. These do not rely on a process model relating pressures to state variables of the water bodies.

3.3 What scale is best to address the comparison?

There was general consensus that agreeing on the scale at which the indicators should be presented is very important also for their interpretation. The issue of the acceptable scale for presenting the JRC pressure indicators was extensively debated at the workshop. The general tendency of the experts was to recommend presenting only very **aggregated maps** (RBD or subunits level) as opposed to water body level, more on grounds of caution to avoid risks of conflict with Member States' assessments rather than on specific considerations for model uncertainty and data reliability.

However models are typically evaluated against measurements at a finer scale than RBD/subunit, and can be usually considered reliable at least for large river basins, although errors tend to increase as we consider smaller basins and should be anyway appraised on a case-by-case basis. Presenting results only at RBD level would prevent from using significant information conveyed by the indicators. The scale at which an indicator is acceptably reliable should be indicated by the modeller (the JRC) based on model verification results.

Also, pressures may be very heterogeneous within one RBD or subunit, hence aggregation at those levels may be misleading and problematic. For instance, the size of the GREEN model sub-basins, on average 180 km^2, may already show mixed conditions of different water bodies.

These two lines of arguments could not find a convergence at the workshop, and no clearly agreed scale for the presentation of results emerged. What was made clear by the experts is the need to avoid that the JRC indicators can be taken for assessment at the water body level; therefore the level of aggregation of results should not go to finer units than sub-basins containing more than one single water body.

Some experts suggested on purpose thresholds of drainage area from 1000 to 5000 km^2, while others pointed out that such thresholds would make the assessment not significant particularly for small countries and where pressures are more significant for smaller rivers.

It has also been suggested that, while indicators should be presented aggregated by relatively coarse mapping units, the frequency distribution of their values may pose less issues in terms of consistency with Member States' assessments, and still convey significant information.

3.4 Can the proposed indicators of pressures be useful in the assessment of the RBMPs? Why?

While indicators are perceived as **useful for a general overview** at the European scale and to identify where a process (pollution, over-abstraction, etc.) is taking place, their usefulness in the evaluation of specific RBMPs seems to depend mostly on the availability of specific information on the **local conditions**.

The indicators related to nutrients were well accepted, although with concerns for the estimation of concentrations, clearly much less predictable than annual loads as they depend on local dilution conditions and have a much higher variability; this is particularly true for intermittent streams widespread in Europe and especially in the Mediterranean). Indicators on chemicals raised more concerns because the model proposed seems too simple and data are too scarce. As several substances are emitted by industries, information about industrial installations should be incorporated more explicitly in the indicators.

It has been stressed that use of the most recent pan-European data on wastewater treatment plants is necessary in order to correctly reflect the measures implemented by the Member States, hence progress in the implementation of the WFD. The source apportionment of observed loads varies across EU and locally and depends on when (and how frequently) the load measurements are taken, and this may represent a limitation of the GREEN model.

Moving to hydrological alteration indicators, it is clear that the basis for the choice of the low flow threshold (10th or 25th percentile of "naturalized" flows) is water stress rather than ecological effects. The term 'environmental flows' or 'ecological flows' should therefore be avoided. In general, it has been observed that interpretation of these indicators is not possible without specific reference to the context. While the WEI can be linked to sustainable water use, it is not fully clear whether it is a useful indicator of hydrological alteration in the perspective of the ecological status. Its argued correspondence with conditions of flow regime alteration needs further testing before practical use in this sense.

Morphological indicators of floodplain alteration and indicators derived from the presence of dams convey messages that are easy to communicate, and can be used to benchmark hydromorphological pressures reported by Member States, even if they lack an underpinning process model. It was noted that the indicators do not take into account mitigation measures; mitigation measures determine whether the good ecological potential (GEP) environmental objective is met.

In order to understand the pressure exerted by the presence of dams, there is a need for better data than is currently available. There is a need to better explain and perhaps further develop specific indictors like the percentage of river length that is dam-free.

3.5 What are the knowledge gaps?

Generally knowledge gaps were identified mostly in the **input data** needed for the calculation of the indicators. Deeper exploitation of the Member States' reports under the WFD might fill this gap, but it seems unlikely that these reports can provide sufficiently coherent and consistent data at EU level. Specific knowledge gaps were identified in **aquifer residence time**, and **metals background** concentrations. For hydrological and morphological alteration, there is a lack of knowledge on the **link** with **ecological status and potential** limiting the possibility to assess the significance of the pressures.

4. Way forward

The JRC will produce updated pressure indicators in the course of 2016. At the end of July 2016, these indicators will be published as a draft for review by experts in the Member States, primarily for scientific verification purposes (i.e. identification of possible inconsistencies with the Member States' assessments and identification of the respective reasons). Experts will be consulted at a later stage on further developments based on these models and indicators, e.g. when used to support 2nd RBMP assessment as well as WFD review by the Commission.

Understanding the reasons for the discrepancies between JRC pressure indicators and Member States' assessments should not add burden to the Member States. In particular discrepancy should not be considered *per se* as evidence of non-compliance in implementation of WFD by Member States.

It will be necessary to pay significant attention to the way the results are communicated, so to clarify the content of the indicators and avert risks of misinterpretation. The planned review of the indicators will serve also this purpose.

List of abbreviations

BOD = biochemical oxygen demand

CSO = combined sewer overflow

EASIN = European alien species information network

GREEN = geospatial regression equation for European nutrient losses

LUSI = Land use simplified index

RBMP=river basin management plan

RPR = reported percentage (of water bodies) at risk (of not achieving WFD goals)

TSS = total suspended sediments

WFD = Water Framework Directive 60/2000/EC

FAO = Food and Agriculture Organization

IFA = International Fertilizer Association

EEA = European Environment Agency

CCM2 = Catchment Characterization and Modelling (version 2)

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