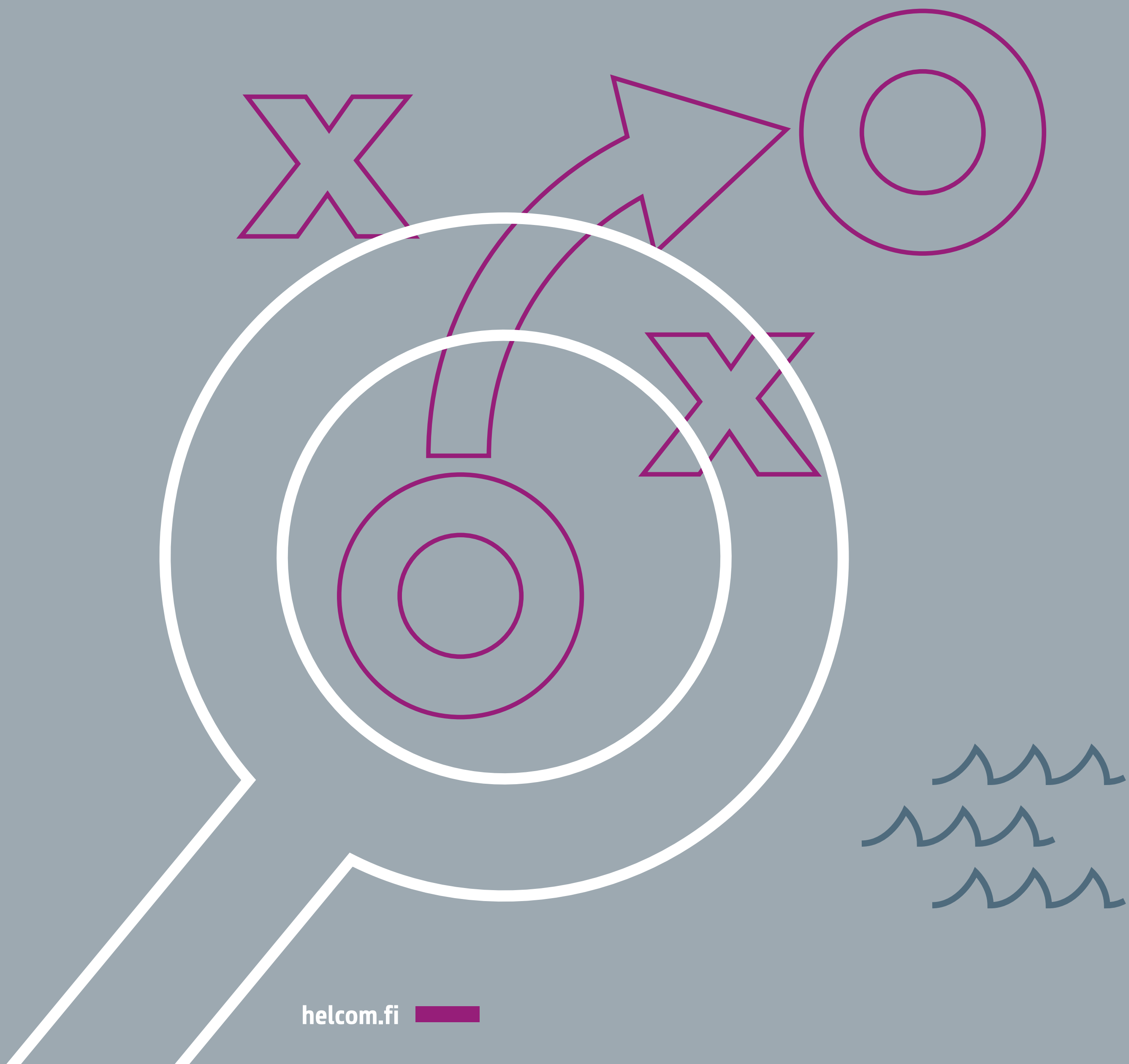
PLC-6

Applied methodology for the PLC-6 assessment

Baltic Marine Environment Protection Commission

Monitoring & assessment



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Applied methodology for the PLC-6 assessment

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Introduction

The HELCOM PLC Guidelines provide guidance on various aspects of the nutrient load assessment, e.g. sampling methodology, calculation of loads from point sources and other sources, quantification of inputs from unmonitored areas, quantification of uncertainty on flow and inputs, calculation of source apportionment, etc.

The Contracting Parties to the Helsinki Convention were requested to report applied methodologies for the PLC-6 assessment by filling in a questionnaire. If countries used methods described in the PLC Guidelines, they referred to it. In case another method was applied, a short description of the methodology was supplied. The applied methods were reported to evaluate the following aspects of nutrient load quantification:

1. Calculation of flow and loads (rivers, direct point sources);
2. Inputs from unmonitored areas;
3. Source apportionment (load and source-oriented approach);
4. Retention;
5. Transboundary inputs;
6. Uncertainty on flow, loads, unmonitored and total inputs and on sources.

Countries forwarded the information during 2017 and 2018 and made some amendments during early 2019. This report contains a compilation of the original reports supplied by national representatives in the HELCOM PLC Implantation Group.

This publication also includes an overview of the reported methodologies and a summary with remarks and discussion on the applied methodologies including the comparability of the results with the used national methods and some identified shortages.

Overview on country methodologies

The table below provides an overview of the methodologies used by the Contracting Parties (besides EU). “Yes” in each cell indicates if a country reports and/or follows the principles/methodology described in the PLC Guidelines. “No” indicates that a national method is applied or that the information is not reported.

After the overview table follows a chapter with summary remarks about the method applied, followed by the Contracting Parties’ input on their methodology. The chapter includes some identified shortages and needs for improvement as indicated in *paragraphs in italics*.

	Flow/Load	Unmonitored areas	Source apportionment	Retention	Transboundary inputs	Uncertainty on inputs & sources
Denmark	Yes. Daily flow and daily concentration (linear interpolation). Chemical and hydrological stations are coinciding. All point sources >30 PE calculated based on monitoring flow and concentrations (sampling frequency depends on PE) Scattered dwelling: estimated based on statistic of number of scattered dwelling, type of wastewater collection/treatment and coefficient of annual TN and TP losses for category. Storm waters: losses relates to statistics and amount of rain	Yes National model estimates flow, diffuse losses of TN and TP (including scattered dwelling). Run off 1*1 km grid, monthly diffuse losses 25-50 km^2 polygons. Diffuse losses for TN based on (soil type, % cultivation, degree of drainage, monthly precipitation, air temperature nitrogen surplus) and TP (based on soil type, % cultivation, regional baseflow index BFI, monthly precipitation and % meadows) Point sources inputs (also monitored in unmonitored areas) added.	Yes. Load and source-oriented approach according to guidelines. Load oriented – agriculture estimate from loads. Minus other sources taking into account retention. Source oriented: Diffuse losses estimated with models (as for unmonitored areas). Atm. dep: calculated on inland surface waters based on monitored deposition on land (of TN and TP)	Yes Calculated for all large lakes individually with a national model. Retention estimate for nearly 6,000 small ponds and lakes based on results from 16 monitored lakes), for streams wider than 2 m and for restored wetlands	Not relevant for Denmark	Yes. Follow the Danish examples in the guideline.
Estonia	Yes. Daily flow daily concentration (linear interpolation). Point sources quarterly reported flow and concentrations.	Yes. National model divided Estonia in three catchments. Average specific run-off per catchment based on monitored part of the catchment	Partly. Source oriented approach based on simple coefficients.	Not described	Yes. Narva River (border) assumed 1/3 of total load is Estonian	Not quantified and reported

Finland	Yes Load: mean monthly concentration multi-plied by mean monthly flow and summed up. Flow proportional sampling. Point sources moni-tored.	Yes By extrapolation from monitored areas	Yes reported (but method not described). Diffuse load based on moni-toring 45 catchments and agricultural losses from 11 small agricultural catch-ments + 4 rivers. SOILN-N for TTN estimates and ICECREAM model for TP. Forestry based on regional forestry statistics	Yes National methods using incoming and outflowing load in a sub-catchment, and load from point sour-ces, agriculture, fores-try, scattered dwel-lings, natural leaching and atm. Deposition of N on lakes, Retention is assumed to be negligible in unmonitored areas	Yes Based on monito-red inputs	Not quantified and reported
Germany	Yes. Load: Daily flow and daily concentration (linear interpolation) or mean monthly flow and monthly concentration depending on the Federal State. Direct point sources based on continuous flow measurements and non-continuous concentration.	Yes. Annual reporting: Based on area proportion method based on the entire monitored area. PLC-6 – periodic reporting: Using the MoRE model to calculate pathway specific loads (coming from point and diffuse sources) and flow from unmonitored areas (summed up for the entire unmonitored area)	Yes. Source oriented approach using results of the empirical based emission MoRE model. Calculations are pathway-oriented.	Is reported The MoRE model provides riverine retention based on the MONERIS retention coefficients for TN and TP (Behrendt & Opitz (1999))	Reported Based on agree proportions of total TN and TP load in Oder	Estimated based on expert judgement
Latvia	Yes Load: mean monthly concentration multiplied by mean	Yes By extrapolation from monitored areas	Yes. Source oriented approach based on land-use and simple export coefficients.	Yes. Follows Behrendt & Opitz (1999) with retention coefficient	Yes. Monitored monthly concentrations and extrapolated dis-charges.	Not quantified and reported for total loads. Estimates for mo-nitoring stations

	monthly flow and summed up. Point source load quantified based on monitoring results			for TN and TP depending on discharge, areas on surface waters in the catchment	Daugava loads divided between RU and BY taking into account catchments areas (guidelines)	using Harmels et al (guideline) formula
Lithuania	Yes: Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point source load monitored? Periodic reporting: Load and flow are modelled with SWAT model (set up for entire Lithuania)	Yes. Using areas proportion method using Minija River concentrations and flows. Periodic reporting: SWAT to model flow ad load from unmonitored areas	Yes National model using average data 2007-2014. SWAT-model use environmental data, climate, point source discharge, agricultural activities etc.) – all sources simulated. Atm dep. Monitored Results calibrate to fit with total monitored loads	Yes. Using SWAT model – calculate retention on all pollutants and sources – and include processes in river channels as sedimentation, resuspension, turn-over of nutrients, diffusion	Yes. Modelling, but for Sventoji area proportion. The models do not cover catchment in other countries and are therefore not working very well. But, Belarussian based on monthly concentrations and daily flow monitored. Inputs through Matrosovka channel is calculated by flow proportional coefficient based on measured data in the channel. Also modelling transboundary inputs from Lithuania to Latvia.	Not quantified and reported
Poland	Yes, partly Not described how load in rivers are calculated.	Yes. Use the area proportion methodology	Yes. Summary of discharges from point sources and diffuse sources and the then the	Yes. Follows Behrendt & Opitz (1999) method	Yes Based on monitored concentration (annual average)	Not quantified and reported

	Point sources- at least one measurement re-quired – calculate load of the day and multiply with 365. Scattered dwellings: TN and TP load 4.4 kg/n and 0.8 kg P per person, statistics on number of not connected person and coefficient of TN and TP entering surface waters according to HARP guidelines. <u>Storm waters</u>: Using HARP guidelines Using paved urban areas connected to combined sewer system, TN and specific TN and TP discharges from paved urban areas (14 kg N/ha and 1.2 kg TP/ha)		shares of these sources of the total discharge. Riverine load calculated according to source apportionment (?) Diffuse sources quantified by dividing Poland in 135 sub-catchments, divided in types: <u>Agricultural land</u>: Monitoring in each catchment of nitrates and phosphates – monitored I 100 drains % of agricultural land pr. catchment Flow from agricultural land. Load= average concentration time average flow Multiplied by a correction factor to take into account other N and P compounds. <u>Forestry and unmanaged land</u>: Use of slope, permeability of soils, N and P concentration in precipitation, flow weighted concentration from managed forestry <u>Atm. Dep.:</u> Based on monitoring TN and TP in precipitation and calculated for inland surface waters		and average flow rate 2012 or flow rate for long term average	

Russia	Yes Load: mean monthly concentration multiplied by mean monthly flow and summed up. Direct point sources based on continuous monitoring (min 12 times per year)	Yes. National model: Limnological Loading Model	Yes. National model: Limnological Loading Model. Model includes annual load, load from point sources, diffuse load from agriculture, diffuse emissions from land surface not affected by agriculture and atm. dep. <u>Point source load</u>: state statistical data <u>Natural and anthropogenic load</u> (excluding agriculture) specific concentrations in runoff from urban areas (scattered dwellings areas), natural background areas and mixed area taking into area and runoff of each of these types. <u>Atmospheric:</u> TN zero, TP 3.2 kg/km^2 <u>Agriculture diffuse</u>: Formula 3 take into account N and P content I plough layer, organic and mineral fertilizer applied, field areas (per enterprise), coefficient related to uptake of organic and mineral fertilizer, nutrient outflow from plough layer, distance from	Yes. Follows Behrendt & Opitz (1999) method: See Russia formulas no. 5-6-7-8. Requires annual load from the catchment direct load to the lake, hydraulic load to the lake, lake percentage in the catchment, specific run-off	Yes. Based on agree proportions used for PLC5.5	Not quantified and reported

			agricultural areas to receiving surface waters, soils types, soil texture, land use structure, status of applying BAT <u>Background load</u>: Take into account coefficient for mass exchange with atmosphere, % lake area and retention factor			
Sweden	Yes. Daily flow and daily concentration (from linear interpolation of monthly concentrations). Point sources monitored loads Smaller point sources estimated based on treatment methodology and number of person equivalents	Yes. Main rivers (43) monitored to the mouths. Minor rivers and coastal areas are estimated with area-specific load estimated from similar rivers in the area	Yes. <u>Source oriented</u>: TN and TP load on lakes and rivers calculated to 23,100 WFD water bodies (11 km^2 in average). Several models used. Inputs from pint sources and diffuse sources. Diffuse source estimated by land use area multiplied by specific runoff and concentration in runoff for the land use. Concentration for agricultural land calculated by the NLeCC – includes SOILNDB for N and ICECREAMDB for P (using fertilizer, manure, atm. Dep., crop yield, catch crops, protection zones, agricultural practices, weather data, crop rotation, soil type, soil P, soil slope).	Yes. National models using SMED-HYPE model in the 23,100 WFD bodies. Take into account river and lake nutrient processes. SMED-HYPE build upon HYPE – but use land use leakage) and local river retention	Not reported in PLC-6. Load from Norwegian and Finnish catchments calculated from Corine Land Cover and land use not including anthropogenic land use sources. For Torne River Finland provides point source data	Not reported

			Specific concentration for land use forest, wetlands, alpine and open land base on representative data based on monitoring campaigns <u>Storm-water</u>: runoff coefficients from statistics <u>Scattered dwellings:</u> Population not connected, load per person, reductions efficiencies of applied techniques <u>Atm. dep.</u> MATCH model <u>Load oriented approach</u> Retention form SMED-HYPE in 23,100 catchments. Calculated at river mouths using total loads from the annual reporting			

Summary remarks and discussion on the applied methodologies

This chapter includes summary remarks on the reported methodologies and some comments on the applied methodologies including the comparability of the results with the used national methods. Some identified shortages and needs for improvement are indicated in the *paragraphs in italics*.

Calculation of flow and loads (rivers, direct point sources)

Two methodologies are mainly applied for river loads:

- Calculated from daily means of flow and daily concentration (daily concentration applied by interpolation)
- Calculated from mean monthly flow and mean monthly concentration

If countries are monitoring water level continuously (as recommended in the PLC Guidelines) and take chemical samples monthly it should be considered to use daily flow and daily concentrations for load calculation to make data more consistent and comparable. Monthly mean methods are overall underestimating loads. Why using monthly means if more frequent sampling is available?

For wastewater treatment plants and industries the method(s) of load estimates depends on both the size of these point sources (big sources higher sampling frequency) and the traditions in the countries. Some countries use daily mean and daily concentration for load calculation of point sources with at least 12 annual samples, other countries use monthly or even annual mean concentration and flow.

There is a need for further harmonizing load calculation methods for both riverine loads and especially for loads from wastewater treatment plants and industry. At present data from these sources – and particularly from minor sources – are not fully comparable and consistent.

For scattered dwellings countries apply country specific losses per PE and some countries take into account the treatment category for scattered dwellings. The applied methodology is quite unclear or not specified for storm waters, e.g. how the amount of precipitation (and intensity of precipitation) is taken into account and how the concentration of chemical compounds has been estimated/assumed?

There is a need to clarify TN and TP per PE for scattered dwellings, how any treatment is taken into account, methods used for quantifying inputs from storm waters, and the completeness of the quantification. These sources (particularly for TP) are of increasing importance and they are the wastewater sources with the highest uncertainty on the *quantified inputs. There is a need to further harmonize the methodologies and the completeness in quantifying these sources.*

For marine fish farms consumption of food (fish production) and food conversion rates are used. For freshwater fish farms food consumption (fish production), food conversion rates and any treatment are used, but at least one country uses monitoring in inlets and outlets to estimate net loads from fish farms. Further, national/regional statistics might be used.

There is a need for further clarifying the N and P content in food, food conversion rates, determining losses from fish production within inland water fish farms, how any treatment, etc. is taken into account, and whether all fish plants are included in the reporting/ assessment. Inputs from aquaculture might be the point source with the most incomparable and inconsistent inputs, and there is a need for further harmonization of TN and TP input quantification methods, and to ensure that all aquaculture activities are included in the assessment.

For other types of aquaculture there seems to be no reporting.

Inputs from unmonitored areas

Inputs are estimated overall by two methods:

- Area proportion (7 countries)
- Specific modelling (2 countries)

The area proportion methods are divided in two sub-methods:

- Upscaling the monitored part of the catchment to the mouth by simple area proportion
- Using discharge weighted concentration from the monitored part of the river or from neighbouring catchment with corresponding characteristics (as land use, soil types, agricultural practices, etc.) to estimate the unmonitored part of the rivers and/or unmonitored rivers. Some countries use discharge weighted concentration from only some selected rivers in all unmonitored parts of the catchment – others are dividing the catchment area in the country into regions and sub-regions

Two countries use a specific model based on soil type characteristics, land use and some specific parameters of agricultural practices, modelled flow, quantified point source losses, etc. to estimate diffuse and/or total inputs from unmonitored areas.

It is not clear how some countries take into account inputs from point sources in unmonitored areas. Is it correct to assume a corresponding proportion of point sources in unmonitored areas as in monitored areas? Do countries have information on point sources in unmonitored areas – then it is only the diffuse part that needs to be monitored/estimated.

When the proportion of unmonitored areas is low (e.g. less than 5-10%) by taking into account the point sources in unmonitored areas, using area proportion/discharge weighted concentration from monitored areas should provide comparable results (if the monitoring result are comparable). When the proportion of monitored areas is higher, it is recommendable to use more extensive modelling and take into account specific characteristics of the unmonitored area. Overall, if information on point sources is available in unmonitored areas, this information should be used.

For countries/catchments with more than 5-10% unmonitored areas the applied methodology is not fully consistent and comparable between countries.

Source apportionment (load and source oriented approach)

<u>Load oriented approach</u>:

- Most countries follow overall the methodology of the PLC Guidelines estimating anthropogenic diffuse losses as the remaining part of the monitored load after subtracting input from point source, scattered dwellings, storm waters, and natural background losses and taking into account retention in inland surface waters.

The load oriented approach accumulates the uncertainty on the anthropogenic diffuse sources. If some of the point sources are not quantified, and if, e.g. inputs from scattered dwellings and/or storm waters are not quantified then the estimated anthropogenic diffuse losses (which usually is seen as an estimate of the inputs from agricultural sources) will be over-estimated. The estimate is also dependent on how natural background losses are estimated, e.g. if they are calculated for the entire catchment. The estimated anthropogenic diffuse sources are also dependent on how retention is calculated and taken into account.

Further, it is quite obvious that it is important to take into account how inputs from unmonitored areas are included in the source quantification of the load oriented approach.

It should be considered to use flow normalized loads for the source apportionment to reduce variability in the diffuse sources.

Although the load-oriented approach uses a more harmonized methodology than the source-oriented approach, further efforts are needed, e.g. on quantifying some of the diffuse sources including natural background, scattered dwellings and storm waters, atmospheric deposition and retention to make results more comparable and consistent.

<u>Source oriented approach</u>:

- Many countries use rather comprehensive models to estimate diffuse sources entering into surface waters (e.g. SOIL-N, ICECREAM, SWAT, MoRE, NLeCC, MATCH, other specifically developed national models). Models range from empirical to physio-chemical process oriented modelling

- Some countries have not fully performed the source-oriented approach
- Some countries model each source/pathway separately, other countries model mainly diffuse sources aggregated
- The size of modelling units varies, some countries use small units (few square kilometres) estimating both flow and different diffuse source for each unit, while other countries model only for large units and are aggregating several sources
- Retention is generally taken into account – some countries in each modelling unit and directed to each source/pathway, and other countries apply a more aggregated approach
- Some countries include inputs from scattered dwellings and storm waters together with other diffuse sources
- Atmospheric deposition on inland surface waters is taken into account (and modelled) by some countries. One country also takes into account atmospheric inputs on the catchment
- Two countries quantify inputs from agriculture and managed forestry separately
- Some countries use annual actual data (one year), other countries an average of several (e.g. 5) years and further, some input parameters to the models might be averaged or aggregated.

Many of the challenges described for the load-oriented approach are also valid for the source-oriented approach.

More substantial modelling is involved in the source-oriented approach as compared with the load oriented approach, including the use of either very small or large modelling units. The results should be compared very carefully between countries and the source data are not very consistent.

There is a need to further discuss where it is relevant to harmonize the methodologies, and the requirements for documenting the applied models, to be able to assess data and facilitate inter-comparison of national source apportionment data. It should be further discussed whether source apportionment (source-oriented approach) could be based on an average of 3 or 5 years and/or normalized data.

A pilot study applying some of the country methods on the same catchment to allow for comparing results could facilitate the evaluation of comparability and consistency of these methods.

Retention

Several methods or approaches are used:

- Monitoring incoming and outflow in sub-catchments
- National model on lakes calculates individually per lake (MORE, SWAT, Behrendt & Opitz (3 countries), SMED-HYPE)
- One country has not described their method

For some countries it is not specified whether retention is taken into account for all lakes, and for several countries it is not described how and whether retention in rivers is included (or relevant). There is a need to calculate retention in all inland surface waters.

It should be clarified whether some countries are including retention in soils, groundwater, etc. in the retention estimates?

It should be discussed whether and how retention estimations take into account the location/distribution of major sources - e.g. if a point discharges in the upper or lower part of a catchment.

There is a need to clarify how retention in connection with flooding is taken into account.

It should be clarified how retention is aggregated from small catchments to the catchment to a Baltic Sea sub-basin.

Countries use rather sophisticated methods for retention, but it would be relevant to compare the applied methods if they provide consistent and comparable results (pilot study applying different methods on the same catchments).

Transboundary inputs

Several methods or approaches are used:

- "Based" on monitoring at the border and take into account retention in the downstream catchment – either by calculation of load at the border, or using flow weighted concentrations
- Based on fixed proportion agreed between two countries, e.g. Narva
- Divide inputs in proportion to division of catchment area
- Modelling approaches
- Based on agreed proportions in PLC 5.5

Some countries use specific methods per river.

Some countries have not reported their methodology.

For some transboundary rivers no estimations are made on the shares between countries.

The estimation of transboundary inputs needs clearly further work on methodology and cooperation between countries including also countries not being HELCOMmembers.

It is obvious for some rivers to monitor inputs at the border, and estimate the retention in the downstream catchment with an agreed method.

But for some rivers crossing the border several times or where the rivers divide in branches, or rivers that are crossing the border of several countries there is a need to agree on a specific methodology for these rivers including how to estimate retention in each country. Overall, for the big/bigger river, sampling at the border is the recommendable method.

For minor rivers it might be possible to divide inputs according to area proportion in the countries if land-use, soil type, hydrology and topography are comparable, and taking into account bigger point sources.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Only two countries have (partly) reported on the uncertainty on flow and load, total loads and sources. Although in the MAI and CART assessments an overall estimate has been calculated on total inputs of TN and TP per sub-basin and country per basin.

Denmark has developed a methodology for estimating uncertainty on monitored load (per river), monitored loads per catchment, unmonitored loads and total loads. The methodology is described in the revised PLC Guidelines (2019).

Latvia has used the formula of Harmel et al. (2006) in the Guidelines to estimate uncertainty on flow measurement and some uncertainty component on loads.

The revised PLC Guidelines (2019) includes a methodology to estimate uncertainties on monitored and unmonitored inputs and total inputs. Further, uncertainty on point source loads could be estimated by the methodology. Uncertainty estimates for sources and how these estimates should be calculated, are closely related to the methodology and model applied in quantifying the sources. Further work is needed to allow for quantifying uncertainty and to make them comparable between sources and countries.

Denmark

Information provided By Lars M. Svendsen (lms@dce.au.dk) and Henrik Tornbjerg (hto@bios.au.dk).

Calculation of flow and loads (rivers, direct point sources)

Denmark overall follows common agreed methodologies. Danish rivers are overall quite small or very small and even reporting 144 monitored rivers Denmark only covers less about half (48 %) of the Danish catchment area to HELCOM convention. It should be remarked that even in unmonitored catchment discharges from point sources >30 PE are monitored.

Denmark has re-reported flow, annual TN and TP inputs for the complete time series (1995 and onwards) also updating some point source data – the main reason for the re-reported being changed methods to estimated losses from unmonitored areas and retention calculation.

The monitoring criteria for point sources have also been unchanged since 1989. The Danish monitoring programme has until recently been focused on nitrogen and phosphorus compounds and organic matter. Since late 1990'ties also some heavy metals and hazardous substances have been monitored on very few, selected rivers and selected major point sources (waste water treatment plants and industries with separate discharge), but these substances are not monitored every year in these rivers. For some heavy metals and most hazardous substances the main part of analysed concentrations have been under the detection limit and no total loads to coastal waters have been calculated as yet.

Analysis has to be performed on accredited laboratories and only few (1-3) laboratories have been involved for the past 4-6 years. Monitoring is until 2006 performed by the Danish Counties, thereafter by the Ministry of the Environment and Food, and they decide which laboratories they contract to perform chemical analysis.

In Denmark all point sources bigger than 30 PE are monitored even if they are situated in the unmonitored (part of) river catchment area. The frequency and sampling method is given in table 1.

Table 1: Annual sampling frequency (minimum) for wastewater treatment plant outflows

Plant capacity (PE)	Frequency/yr (min.)	Sampling method
$30 \leq x < 200$	2	Random samples [1)]
$200 \leq x < 1{,}000$	4	Time-weighted daily samples [2)]
$1{,}000 \leq x < 50{,}000$	12	Flow-weighted daily samples
$50{,}000 \leq x$	24	Flow-weighted daily samples

1) Time-weighted samples, random samples or empirical values, and 2) Time-weighted samples or random samples if the necessary facilities for collection of flow-weighted samples are not available. PE: Person equivalent to be equivalent to 21.9 kg organic matter per year measured as biochemical oxygen demand (BI_5), 4.4 kg total-N per year or 1.0 kg total-P per year for some years, but the P-value will be reduced in future.

Measurement of the water volume discharged is in general continual registration of the water volume on the day in question.

Calculation of total discharges follow the PLC guidelines.

Plants with a capacity > 500PE covers 99% of the total wastewater load to wastewater treatment plants.

In Denmark all point sources bigger than 30 PE are monitored even if they are situated in the unmonitored (part of) river catchment area. The frequency and sampling method is given in table 2.

Measurement of the water volume discharged is in general continual registration of the water volume on the day in question.

Calculation of total discharges follow the guidelines.

Many heavy metals and hazardous substances are monitored at selected waste water treatment plants and separate discharging industrial plant.

Table 2 Discharge classes for industries with separate wastewater discharges indicating the amount of nitrogen (total-N), phosphorus (total-P) and organic matter (BI_5 (modified) and COD) discharged together with the sampling frequency.

Discharge class	Discharge (tonnes/yr)				Frequency/yr
	BOD_5 (mod.)	COD	Total-N	Total-P	
I	0.6 < x < 4.3	1.6 < x < 10.8	0.13 < x < 0.9	0.005 < x < 0.3	2 samples
II	4.3 < x < 21.6	10.8 < x < 54	0.9 < x < 4.4	0.3 < x < 1.5	4 samples
III	21.6 < x < 108	54 < x < 270	4.4 < x < 22	1.5 < x < 7.5	12 samples
IV	x > 108	x > 270	x > 22	x > 7.5	12 samples

Stormwater and scattered dwelling

TN and TP loads are based on statistical information. For stormwaters it used statistics on outlets with rainwater from fortified areas and from overflows with sewage and rainwater. Precipitation is used in the calculation of TN and TP losses.

For scattered dwellings for each household information of type of waste water cleaning system get a theoretical degree of purification, which is combined with number of inhabitants in different types of households and excretion of TN and TP per person (PE) (annually 4.4 kg TN, 1 kg TP (this number is under revision and will be lowered markedly) and 21.9 kg BI_5).

Rivers

The annual sampling frequency at each river monitoring site is generally 12-18. Stage (water level) is recorded continuously (either sampled every 10 minutes or averaged over 10 minutes) at all river monitoring stations. Discharge (cross section of river monitored in several depths in several depth profiles) is measured at least 12 times per year, and continuously run off is calculated using a well-established stage-discharge relationship which take into account any impounding effects on stage caused by aquatic plants. Transport at each river monitoring station is calculated by multiplying daily discharge with daily concentration, the latter estimated by linear interpolation of measured values.

Inputs from unmonitored areas

Denmark has developed a new standardised method for estimating diffuse losses and loads from unmonitored areas. The new models estimates run off, diffuse losses and loads of nitrogen and phosphorus respectively. To these loads, the load from point sources in unmonitored areas is added. As explain earlier all discharges from point sources >30 PE are monitored, and discharges from scattered dwelling are based on information on number of scattered dwellings and which kind of purification the individual scattered dwellings have. Discharges from storm water overflow are estimated based on precipitation and e.g. the fortified are connect to e.g. an overflow pipe.

Shortly described run-off is calculated for 1 * 1 km grids with use of The National Water Resources Model from Geologic Survey of Greenland and Denmark (the so called "DK-model"), but adjusted and calibrated by NERI with discharge measurements in a lot of rivers to fit with monitored run off in rivers. The run-off is aggregated to monthly values and for 25-50 km^2 polygons (catchments).

Further two models calculate nitrogen and phosphorus monthly flow-weighted concentrations, respectively for different unmonitored catchments. Calculations of diffuse losses are done on a monthly basis for 25-50 km^2 polygons (catchments). These flow- weighted concentration are multiplied by the calculated flow from 1*1 km grid to calculate diffuse losses including natural background losses. Relevant point source discharges are added. Thereafter retention of nitrogen and phosphorus in rivers, lakes and wetlands are deducted from the calculated diffuse losses to get estimate of the riverine loads in unmonitored areas. Retention are estimated using lake retention models, denitrification and net retention of phosphorus in rivers and wetlands (and due to flooding) and taking into account lake, river and wetland characteristics.

The nitrogen model are based on data from 84 agricultural catchments without big lakes and the monthly flow weighted nitrogen concentrations are calculated for 25-50 km^2 polygons as a function of:

- soil type (% sandy soils) (based on map scale 1:500000)
- percentages of cultivation (from central detailed database)
- degree of drainage (based on 205*205 m raster map)
- monthly precipitation (daily data from 10*10 km grids)
- monthly average air temperature (daily from 20*20 km grid)
- nitrogen surplus based on national

The phosphorus model are based on data from 24 agricultural catchments without big lakes and the monthly flow weighted nitrogen concentrations are calculated for 25-50 km^2 polygons as a function of:

- soil type (% sandy soils) (based on map scale 1:500000)
- percentages of cultivation (from central detailed database)
- regional baseflow index (BFI) based on geo-region type, soil type and amount of organogenic soils
- monthly precipitation (daily data from 10*10 km grids)
- percentages of meadows, bog and moor and nitrogen surplus based on national

The total run off and load of nitrogen and via rivers from Denmark since 1995 have therefore been recalculated with the above mentioned new models, and that is the reason for tree-reporting the complete flow and TN and TP loads time series for the PLC-6 assessment. In average for Denmark, the new models results in lowering annual nitrogen loads via rivers with 6-7 %, but on an annual basis with from approx. 15 % lower up to the same loads as compared with former reporting. Concerning phosphorus loads via rivers in average the revised load are 6 % higher, but on an annual basis loads is between 10 % lower to + 15 % higher compared with former reporting. In some catchments there are some major differences compared with former results, and DCE are investigating the reasons behind.

For further details see. **A distributed modelling system for simulation of monthly runoff and nitrogen sources, loads and sinks for ungauged catchments in Denmark.** / Windolf, Jørgen; Thodsen, Hans; Troldborg, Lars; Larsen, Søren Erik; Bøgestrand, Jens; Ovesen, Niels Bering; Kronvang, Brian. I: Journal of Environmental Monitoring, Bind 13, 2011, s. 2645-2658.

Source apportionment (load and source oriented approach)

Denmark follow the PLC guidelines for the load and source oriented approach.

Atmospheric inputs is calculated on inland surface waters based on national monitoring program and dry and wet deposition of nitrogen which then are modelled to and annual deposition rate. For phosphorus deposition Denmark use 0.04 kg P/ha surface inland waters.

Retention

Retention are modelled for larger lakes, small ponds and lakes, streams and restored wetlands.

Larger lakes:

All larger lakes for which both an inlet and an outlet has been identified are in this context defined as larger lakes. For each lake, the external annual nitrogen load has been estimated using the aboved mentioned model and the annual nitrogen-retention is calculated using a N-retention model. The lake N-retention model includes water residence time and average lake depth. The model is based on monitoring data on annual inflow and outflow of water and nitrogen from 21 lakes over a 15 year period.

Small ponds and lakes:

The Danish landscape is dotted with more than 100.000 small ponds and lakes. With the aim to identify the number of minor lakes having a significant potential for N retention the following criteria were established

- Each lake should at least have an identifiable stream outlet and/or "have contact" with at least two ditches. A total of 5930 smaller lakes were identified to meet the criteria.
- No topographic catchment areas are available for these lakes. Hence the calculation of nitrogen retention is based on assigned lakes area specific mean annual retention rates between 60 and 400 kg N ha-1 per year.
- The ranges of retention rates aims to reflect the differences between lakes located in areas with varying farming intensities and varying soil characteristics.
- Inter-annual variation in the area-specific N retention rates is calculated based on the assumption that it follows the relative inter-annual variation in nitrogen retention in determined from mass balances in 16 Danish lakes.

Streams. The calculation of nitrogen retention in streams are based on 41 referenced studies of nitrate denitrification in streams and rivers in different parts of the world reviewed by Kronvang et al. These showed that annual average nitrate denitrification rates were higher in stream channels wider than 2 m than in stream channels less than 2 m wide. The total length of the different width classes was extracted from a national dataset. Inter-annual variation in N retention rates in streams is presumed to parallel the relative inter-annual nitrogen retention in 16 larger Danish lakes.

Restored wetlands. Experience from Denmark following the effect of restored riparian wetlands shows a net removal of nitrogen amounting up to 190 kg N per hectare restored wetland per year. Data on the location of restored wetlands in Denmark since 1998 are recorded in GIS and information on the annual areas of restored wetlands is extracted and stores in GIS. Inter-annual variation in the nitrogen retention rate is assumed to parallel the inter-annual variation in nitrogen retention in 16 larger Danish lakes.

Transboundary inputs

Denmark has no transboundary rivers to take into account.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Denmark have been working with estimating uncertainty on inputs using the method below. The example is for total nitrogen. Uncertainty estimates Is described for monitored, and unmonitored areas separately, and for total inputs to the sea.

Monitored area:

The calculation of the uncertainty is done by using the statistical principle “Propagation of errors”. This principle can be explained as:

Let *X* be the sum of *n* stochastically independent measured loads

$$X = \sum_{i=1}^{n} X_i. \qquad (3,1)$$

The variance of *X* can be calculated as

$$\sigma_X^2 = Var(X) = \sum_{i=1}^{n} \sigma_{X_i}^2. \qquad (3,2)$$

The standard deviation is then calculated as

$$\sigma_X = \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \qquad (3,3)$$

And the relative standard deviation (denoted the precision) is calculated as

$$100 \cdot \frac{\sigma_X}{X} = \frac{100}{\sum_{i=1}^{n} X_i} \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \qquad (3,4)$$

The calculation of the total inputs from the monitored areas constitute of measurements from 169 stations in streams. These stations cover approximately 55% of the total Danish catchment area. Bias and precision can then be calculated as

$$bias\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sum_{i=1}^{169} bias_i \cdot X_i, \qquad (3,5)$$

$$precision\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sqrt{\sum_{i=1}^{169} (precision_i \cdot X_i)^2}. \qquad (3,6)$$

The total uncertainty can then be calculated as

$$uncertainty\ (\%) = \frac{100}{\sum_{i=1}^{169} X_i} \sqrt{\sum_{i=1}^{169} (bias_i \cdot X_i)^2 + (precision_i \cdot X_i)^2}. \qquad (3,7)$$

A Monte Carlo study (Kronvang & Bruhn, 1996) has shown that for Danish streams categorized by their catchment area, the following values for bias and precision are valid for nitrogen load:

0-50 km^2: Bias: -1% to -3%; Precision: 1-3%

50-200 km^2: Bias: -0.7% to -3%; Precision: 1-3%

>200 km^2: Bias: -1% to -4%; Precision: 2-5%

These number are valid for the yearly load from one stream station and include the uncertainty of laboratory analysis, yearly variation of concentrations and stream discharge and uncertainty from the method for calculating yearly load (by linear interpolation). The uncertainty from the measurement of the concentration in the stream (placement of bottle horizontal and vertical in the stream) is not included and therefore 2% is added to the precision in the 3 categories.

Using the formulae, it can be calculated that the total bias is -1% to –3%, the total precision is 0.7% to 1.2% and the total uncertainty is 0.7% to 1.3%. For an average stream station the bias is -1% to -3%, the precision is 3% to 5% and the uncertainty is 3.2% to 5.8%.

Unmonitored areas

The nitrogen input from the unmonitored areas is based on model estimates for 1286 very small catchments covering the rest of the Danish area (45%). The year load from each small catchment is calculated using the formula

$$L = Ndiffuse_{model} + R_{lake} + R_{stream} + N_{waste} - R_{total},$$

where $Ndiffuse_{model}$ is the estimated nitreogen inputs from the model, R_{lake} is estimated nitrogen retention in lakes, R_{stream} is estimates nitrogenretention in streams, N_{waste} is nitrogen load from waste water and R_{total} is the total nitrogen retention.

Bias and precision for these components

Components	Bias (%)	Precision (%)
Model	-15 to 25	12 to 15
Retention lake	-5 to 5	40
Retention stream	-5 to 10	40
Retention total	-5	40
Point source: industry	-1 to -3	1to 10
Point source: waste water	-1 to -3	1 to 10
Point source: fish farms	-1 to -3	1 to 20
Point source: rain water	-5	40

Using the formulae (3,1) to (3,7) the total bias for the unmonitored area is calculated to 20% to 28%, the total precision is 0.8% to 2.0% and the total uncertainty is 1.2% to 2.2%. For an average small unmonitored catchment the bias is 27%, precision 15% to 20% and the uncertainty 31% to 34%.

For the total Danish catchment area, combing the calculated bias, precision and uncertainty for both the monitored and unmonitored areas and using special versions of formulae (3,7) to (3,9), we get a total bias of 7,4% to 12,8%, a total precision of 0,5% to 1,1% and a total uncertainty of 7,4% to 12,8% on total nitrogen inputs.

With respect to total phosphorus (TP), calculations show that for the measured area the bias is -6 to -3%, the precision is 1 – 2% and the uncertainty is then 1 – 2.5%. For the unmeasured area the bias is between -5 and 30%, the precision is 1 – 3% and the uncertainty is 1 – 4%.

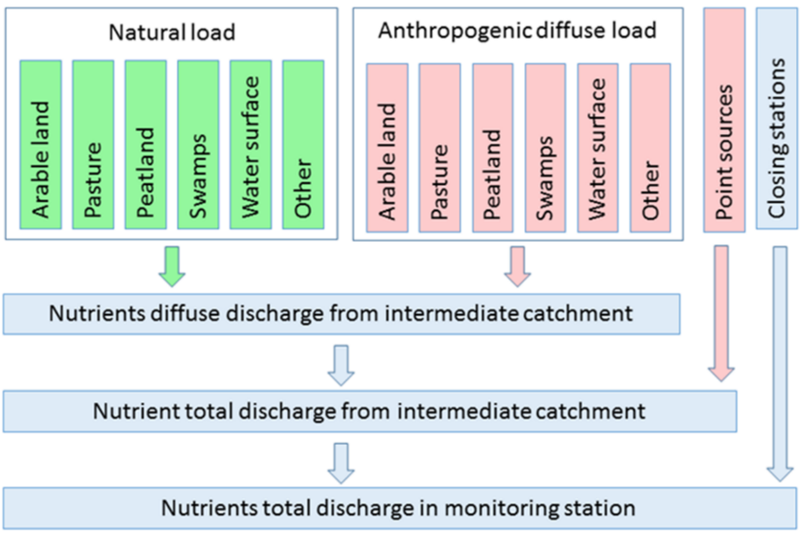
Estonia

Information provided by Peeter Ennet, E-mail: Peeter.Ennet@envir.ee

Calculation of flow and loads

The calculations are carried out according to PLC-6 Guidelines. The annual load for every monitored river is calculated for the measurement site. The load from the unmonitored part of the river catchment area is estimated as a part of the unmonitored areas (GUF, GUR, BAP).

The amount of monitored rivers, reported for Helcom varies slightly and currently the number of these rivers is 15. Among these rivers is one transboundary river (Pärnu river) and one border river (Narva river). All our monitored rivers have both hydrological and chemical measurements stations however, in some cases these stations are not located in the same place. For unmonitored load calculation and for compilation of periodic report a simple coefficient-based model (EstModel) is used. Nutrinent discharges from diferent land types are calculated separately. Loads from point sources in intermediate catchment are calculated individually. The load from each source is divided into natural load and anthropogenic load.



Estmodel calculation units (load types).

EstModel is calibrated against the measured annual load data at the sites of every chemical monitoring stations.

Flow in chemical station

If hydrological station is not in the same place with chemical station then taking into account the fact that the distances between stations are not big the flow in chemical station is calculated:

$$Q_{ch.st.} = Q_{hyd.st.} \frac{S_{ch.st.}}{S_{hyd.st.}}$$

$Q_{ch.st.}$ – flow in chemical station

$Q_{hyd.st.}$ – flow in hydrological station

$S_{ch.st.}$ – catchment area in chemical station

$S_{hyd.st.}$ – catchment area in hydrological station

The annual input calculation using daily river flow and daily concentration (interpolated)

We have daily flow data and monthly chemical data. Using linear interpolation the concentrations (C_t) for days where pollutants have not been measured are calculated. The annual input (*L*), as kg a^{-1}, is estimated by:

$$L = 0.0864 \sum_{t=1}^{n} (Q_t \cdot C_t)_t$$

$\sum$ - denotes summation

n - number of days

C_t - daily concentrations C for day t

Q_t - daily flow Q for day t

Concentrations are given in mg l^{-1} (for nutrients – for heavy metals, concentrations are given as µg/l), river flow as l s^{-1}. The estimate in the equation is multiplied by 0.0864 to obtain the daily loads that are summarized in the equation over the whole year for nutrient and by 0.0000864 for heavy metals.

Values under the limit of quantification

If measured concentrations are below limit of quantification (LOQ), the estimated concentration is calculated using the equation:

Estimation = ((100%-A) • LOQ)/100

where A=percentage of samples below LOQ

Quantification of inputs from point sources.

Load from point sources is calculated on the basis of quarterly reports forwarded to our Agency of Environment. These reports must provide four times a year every water consumer who has permission of water use. These reports contain quarterly average concentrations and quarterly total flow. The annual inputs in kg a^{-1} is calculated as follows:

$$L = \sum_{i=1}^{n} Q_i * C_i * 0.001$$

L - annual inputs (kg a^{-1})

Q_i - wastewater volume of period i (m^3)

C_i - average concentration of period i (mg l^{-1})

n = 4, number of quarters in the year

Rainwater drainage from small wastewater treatment plants (separating tanks) and scattered dwellings are estimated as a diffuse load.

Load from scattered population.

Load from scattered population is considered as an anthropogenic diffuse source and it is calculated as

$$L_{scattered}^{N,P} = PE^{N,P} * l_{PE}^{N,P} (1 - R_{catchment}^{N,P}) *365/1000$$

where

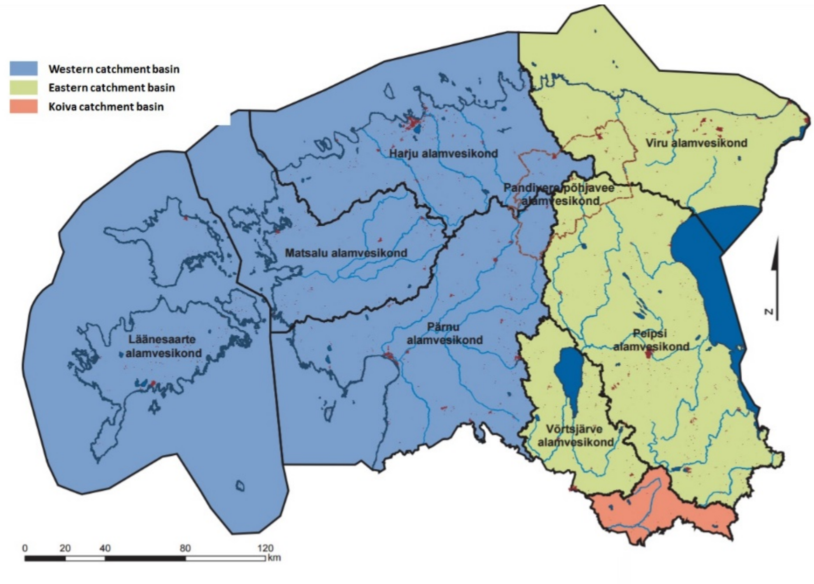
$L_{scattered}^{N,P}$ – N, P load from scattered dwellings, kg/a;

PE – scattered population, as population equivalents;

$l_{PE}^{N,P}$ – population equivalent value (12 g/d for nitrogen and 1,5 g/d for phosphorus);

$R_{catchment}^{N,P}$ – retention (in model $R_{catchment}^{N,P}$=0.95 is used for scattered population load, 365 – days in year, 1000 – grams in kilograms)

Unmonitored area calculation



Estonia is divided into three catchment basins (Western, Eastern and Koiva) and into eight sub-basins (Läänesaarte, Matsalu, Harju, Pärnu, Viru, Peipsi, Võrtsjärve and Koiva). We calculate average specific runoff for every subcatchment area. For the unmonitored area inside the subcatchment we use the average specific runoff of this subcatchment. Monitored and unmonitored areas may be different for different parameters depending on the monitoring program.

For compilation of periodic report (source-orientated approach) a simple coefficient-based model (Estmodel) is used. This model is now under development and the first priority is to get more realistic coefficient values. A short description of this model is presented in: *Ennet, P., Pachel, K., Viies, V. Jürimägi, L, Elken, R. (2008). Estimating water quality in river basins using linked models and database. Estonisan Journal of Ecology, 57(2), 83-99.*

Source apportionment

Quantifying diffuse losses of nutrients from monitored areas

At the moment the diffuse load of nutrients is calculated provisionally in a simplified form.

$$L_{diffuse} = L_{total} - L_{point} - R$$

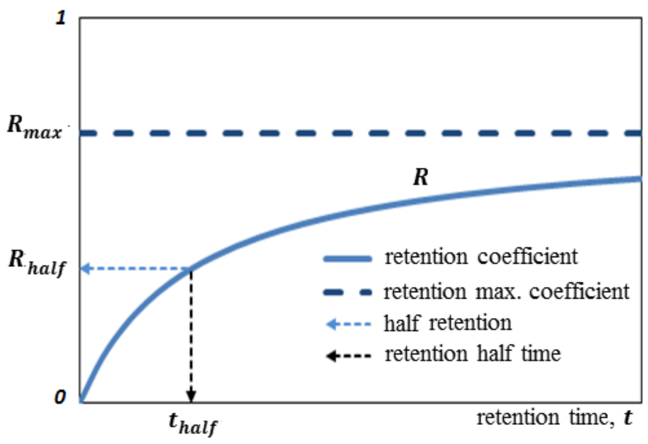
$L_{diffuse}$ - annual diffuse inputs (kg a^{-1})

L_{total} - annual total inputs according to measurements in chemical stations (kg a^{-1})

L_{point} - annual point sources inputs (calculated as sum of quarterly reports forwarded to Agency of Environment) (kg a^{-1})

R - retention coefficient (it is assumed that the loss due to retention is 10%)

Annual inputs from point sources is calculated on the basis of reports forwarded to Agency of Environment taking into account the retention.



Atmospheric load.

Atmospheric load onto water surface area is 440 kg TN/km^2/a and 8.1 kg TP/km^2/a long-term average of monitored data in Estonia).

Natural background losses.

Natural background losses are calculated on the basis of natural concentration. The natural concentrations in calculations are 1,21 mg/l total nitrogen and 0,04 mg/l for total phosphorus.

Anthropogenic load.

In EstModel the nutrient concentration includes the anthropogenic component and natural component. So it is possible to estimate the effectiveness of N, P mitigating measures (reducing the pollution of point sources, limiting the fertilization of fields, creating buffer zones).

Calculation of retention

Load decrease due to retention:

$$L\_ret^{N,P} = L^{N,P} * R^{N,P}$$

where

$L\_ret^{N,P}$ – N, P load decrease due to retention;
L – input load;
$R^{N,P}$ – N, P retention coefficient;

The Michaelis-Menten formula is used in EstModel to calculate retention. The value of retention factor depends on time.

$$R^{N,P} = R^{N,P}_{max} \frac{t}{t^{N,P}_{half} + t}$$

where

$R^{N,P}$ – N, P retention coefficient (0 - 1);
$R^{N,P}_{max}$ – N, P retention max. coefficient (0 - 1);

t_i – retention time ;
$t_{half}^{N,P}$ – retention half-time ;

REMARKS

1. Currently our databases are under development and checking. It appears that we have problems with the accuracy of the historical data, especially concerning the point sources.
2. Since from 2015 we do not have permission to measure flow in Narva river. For 2015 we are using the estimated flow for Narva river. The load from Narva river is an essential part of the Estonian total load.

Transboundary inputs (Border river)

Estonian and Russian common border river is Narva river (total catchment area 58126 km^2, Estonian part is 30,2 %). It is agreed that Estonian part is 1/3 of total load. Estonia has in Narva river 2 hydrochemical stations (7 km from mouth and outflow from Peipsi), 2 hydrological stations (20 km from mouth outflow from Peipsi). Unfortunately, since 2015 the hydrological measurements are stopped (Russian authorities do not give permission). Year 2015 load is still calculated on the basis of estimated flow and since 2016 Estonia has to report Narva river catchment as unmonitored area.

Uncertainty on flow, loads, unmonitored areas and total inputs and on sources

Uncertainty are not estimated.

Finland

Information provided by Antti Rääke (antti.raike@ymparisto.fi)

Calculation of flow and loads

Riverine discharges

Altogether 30 monitored rivers were included in the PLC-6 work. These monitored rivers comprise about 90% of the Finnish Baltic Sea catchment area. Water flow was measured continuously in each river and water quality samples were taken flow proportionally, usually 12 to 20 times per year. Load from unmonitored areas was estimated by extrapolating the results of the nearby monitored catchment areas (with same type of land use and soil characteristics). The annual river discharges for nutrients were calculated by multiplying the mean monthly concentration by the monthly flow and summing up the monthly loads. Missing monthly concentrations were replaced with seasonal means.

Estimation of loading

Point source load

Nutrient load estimation from municipalities and industrial plants were based on regular measurements made according to the guidelines given by the Finnish environmental authorities. In some cases it is impossible to separate municipal and industrial discharges, because especially waste waters of food production plants is usually treated in municipal waste water treatment plants. Nutrient load estimation for fish farms was based on production statistics, amount of feed and nutrient content of the feed, using the equations in the PLC-6 Guidelines.

Source apportionment

Source apportionment was based on the measured (point source) or estimated (diffuse) load figures and retention calculations.

Diffuse load

Small drainage basins and small experimental areas were used in the estimations of diffuse source loading. The network of drainage basins for water quality monitoring consists altogether of 45 basins with different type of land use in different parts of the country. Water flow was measured continuously and water quality samples were taken flow proportionally 35-55 times per year.

Estimation of the losses of phosphorus and nitrogen from agricultural land to surface waters in Finland is based on the monitoring of N and P fluxes from 11 small agricultural drainage basins and from four agriculturally loaded river basins in south and southwestern Finland (Rekolainen et al. 1995, Vuorenmaa et al. 2001). The size of the small basins vary from 0.12 to 15 km^2, and the river basins from 870 km^2 to 1300 km^2. The agricultural land use of the basins varied from 23 to 100%. The monitoring schemes were based on continuous water flow measurement and flow weighted water quality sampling. Using this data, annual N and P flux estimates were calculated, by subtracting possible point-source loads and estimated losses from forested areas and the natural background. The up-scaling of the losses of phosphorus to cover whole Finnish arable land area is based on the ICECREAM model, which takes into account the topography, the structure of soil and agricultural production in different river basins (Tattari et al. 2001). The hydrology of the original model has been modified for Finnish conditions. The most remarkable change is in the model the inclusion of snow accumulation, snow melt and soil frost processes. For nitrogen SOILN-N model was used (Johnsson et al. 1987).

The effects of forestry activities (ditching, clear-cut felling, ploughing, hummocking, fertilization etc.) were evaluated on the basis of regional forestry statistics. The specific yearly net load from forestry activities was approximated using leaching coefficients obtained from the Finnish and Swedish surveys.

Nutrient inputs from scattered dwellings were estimated on the basis of estimated annual waste water production per person and the level of equipment in handling of lavatory and sanitary wastes (table 1). Per capita load estimates were 50 g/d BOD, 14 g/d NTOT and 2.2 g/d PTOT.

Atmospheric deposition on lake surfaces was gained by multiplying specific deposition by the surface area of the lakes. Deposition was measured on 13 stations located in the river catchment areas. Nutrient concentrations were analysed from the integrated monthly samples of rain water.

The estimation of natural leaching was based on coefficients obtained from the monitoring programmes of small drainage basins (table 2).

Table 2. Natural leaching coefficients for different parts of Finland.

	kg P km^{-2} a^{-1}	kg N km^{-2} a^{-1}
Southern Finland	6	200
Central Finland	5	120
Northern Finland	5	80
Northern Lapland	2	50

Calculation of retention

The estimation of retention of nutrients in freshwater is based on mass balance calculations. Usually retention of nitrogen and phosphorus was calculated only for the whole catchment area, but in larger river basins it was also calculated for sub-catchment areas in case there were continuous flow measurements and representative concentration measurements (at least 12 times per year). Retention was calculated using data from 2008 - 2014.

The retention was calculated according to the following formula:

$RET = Q_{IN} + (L_{POINT} + L_{AGRI} + L_{ATM} + L_{FOREST} + L_{SCAT} + L_{BACK}) - Q_{OUT}$, where

Q_{IN} = incoming riverine load

Q_{OUT} = outflowing riverine load

L_{POINT} = point source load (industry, municipalities, fish farming)

L_{AGRI} = agricultural nutrient load

L_{ATM} = direct atmospheric deposition to the lakes

L_{FOREST} = load from forestry activities

L_{SCAT} = load from scattered dwellings

L_{BACK} = natural leaching

Retention of nutrients in freshwaters is in Finland mainly connected to chemical, physical and biological processes taking place in lakes. Unmonitored river catchments and coastal areas in Finland have only very limited amount of lakes, and thus retention in these areas is negligible.

Tranboundary inputs

No information provided.

Uncertainty on flow, loads, unmonitored areas and total inputs and on sources

Uncertainty are not estimated.

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Germany

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Calculation of flow and loads (rivers, direct point sources)

Flow and river loads

The load calculations made for German rivers correspond to the recommendations of the PLC-6 Guidelines.

There are numerous and generally, quite small rivers that drain the German Baltic Sea catchment area. Not all of them are monitored and the number of monitored rivers may vary from year to year. For PLC-6 Germany reported 24 monitored rivers which cover about 66 % (about 16.000 km² including the national area of the Stettiner Haff) of the German Baltic Sea catchment area (except the transboundary German catchment area of the river Oder).

The annual load calculations are based on daily river flows and water quality samples that are taken between 10 to 24 times per year. The applied load calculation methods differ between the two German federal states ("Bundesländer"). Schleswig-Holstein calculated the river loads with daily flow and daily interpolated concentrations while Mecklenburg-Vorpommern applied the method using monthly flow and mean monthly concentration.

Direct point source loads

Germany reported 29 municipal and 3 industrial direct dischargers. There are no directly discharging fresh water fish farms in the German Baltic Sea region.

Flow is measured continuously and concentrations are measured frequently. The legally necessary sampling frequency is specified on the federal level usally depending on plant size. Measurements are carried out by the operator of the plant and controlled by responsible federal authorities using standardized DIN methods.

Inputs from unmonitored areas

Altogether about 34 % (about 8.100 km²) of the German Baltic Sea catchment area is not monitored (about 33 % in WEB and about 30 % in BAP (including German catchment area of the Stettiner Haff)).

For annual reporting calculations of inputs are based on flow and loads from monitored areas assuming similar conditions (concerning inputs from point and diffuse sources) prevailing in unmonitored areas. Loads calculated for all monitored areas are assigned to the unmonitored area based on their proportion. This method may lead to an over- or underestimation of inputs.

For periodical reporting the MoRE (Modelling of Regionalized Emissions; https://isww.iwg.kit.edu/MoRE.php; Fuchs et al. 2011, 2017) model is used to calculate flow and loads for unmonitored areas. MoRE calculates pathway-oriented nutrient and pollutant inputs to surface waters independent of whether the area is monitored or unmonitored (see the following paragraph: “source oriented apportionment”). All relevant pathways (including all point sources (UWWTPs > 50 p.e. and scattered dwellings (defined < 50 p.e. – individual system) and the relevant diffuse pathways) are included.

Source apportionment (load and source oriented approach

Germany generally applies the source oriented approach using nutrient input results from the MoRE model.

The MoRE model is a free software tool for an empirical-based quantification of annual nutrient and pollutant emissions in river basins. It allows a regional and pathway specific quantification for any given aggregation unit. MoRE is based on the MONERIS concept that was developed for modelling of nutrient emissions into the water bodies (Behrendt et al., 2000). The model was later extended to include pollutant emissions.

The considered pathways can be classified into three blocks (Figure 1):

- Pathway-dependent on point-source
  - municipal wastewater treatment plants (MWWTP)
  - Industrial dischargers
- Pathway-dependent on diffuse non-urban sources and
  - Surface runoff
  - Erosion
  - Groundwater
  - Tile drainage
  - Direct atmospheric deposition onto surface waters
- Pathway-dependent on diffuse urban sources
  - Storm water sewer overflows
  - Combined sewage overflows
  - Small wastewater treatment plants (individual systems e.g. septic tanks).

MoRE calculates the inputs based on analytical units (average size 130-150 km²) based on the drainage network. The analytical units can be aggregated to different administrative units, hydrological subbasins, river basins or marine catchment areas.

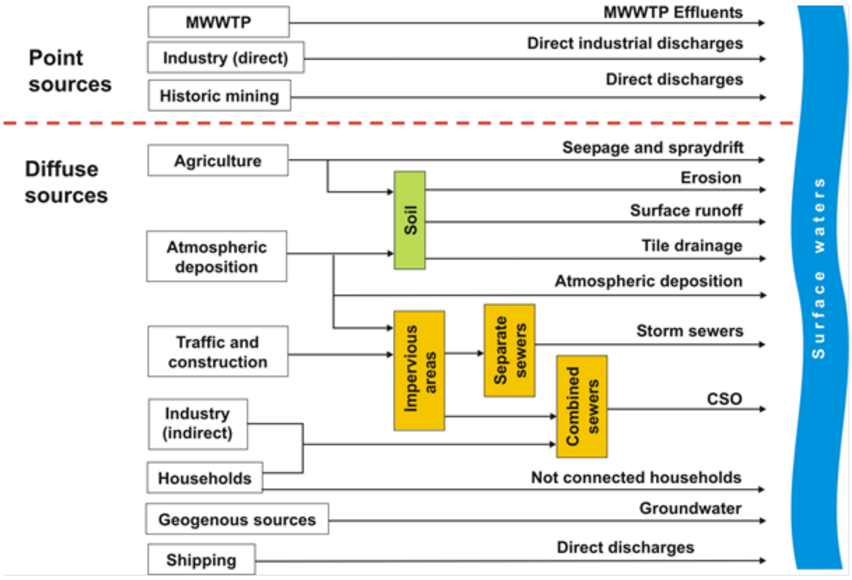

Figure 1. Sources and emission pathways considered in MoRE model (Fuchs et al. 2010; European Commission 2012, Fuchs et al. 2017).

The calculation of emissions from point sources can be straightforward, as data on effluent concentration and the amount of treated wastewater are available or can be derived from statistical data with the required accuracy.

The inputs caused by diffuse non-urban sources are the result of more or less complex interactions with different interfaces, including temporal storage, transformation and losses. These processes have to be integrated into the approaches adequately. Pathways from agricultural diffuse sources include erosion, surface run-off, tile drainage, seepage and spray drift. To calculate direct atmospheric deposition onto surface waters e.g. EMEP products (ecosystem specific deposition) are used. Atmospheric deposition onto land surfaces is not considered separately but included into the other emission pathways (e.g. in surplus calculation for agricultural lands).

The diffuse urban pathways account for various sources including air pollution, wastewater from industries and households as well as primary emissions from construction material and traffic.

To estimate natural background losses of nutrients a separate model scenario was defined and a MoRE simulation was run. The scenario was defined as pristine. Therefore, the entire German Baltic Sea catchment area (except water surfaces) was assumed to be completely forested without any anthropogenic activity (no fortified area, no population, no point sources). Taking into account obvious lower atmospheric deposition either onto surface waters or onto land surface, nutrient emissions were calculated. Hydrologic conditions were assumed to be unchanged from today.

To satisfy the requirements of the load-oriented approach the MoRE results could be used as well. Actually, the model itself does not distinguish between load-oriented and source-oriented approach. However, taking retention into account the propotions of calculated pathways could be used to apply the load-oriented approach.

Retention

The MoRE model considers riverine retention based on sub-basin specific retention factors (Behrendt and Opitz, 1999). Other retention processes (in soils, groundwater, …) are indirectly includes in the pathway calculations.

Transboundary inputs

In Germany there is one transboundary river, the river Oder. The river Oder enters the Baltic Sea on the territory of Poland. The German territory covers 4.7 % of the entire catchment area operating two hydrochemical (one of them on PL border) and three hydrological stations. The Oder is crossing from Poland into Germany and back to Poland and is bordering the two Countries for some reaches. Therefore, Germans monitoring station do not represent inputs only from Germany. To estimate transboundary inputs coming from the German territory, agreed proportions of total TP (3.1 %) and TN (5.5 %) inputs are used.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainties were estimated based on expert judgement.

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LATVIA

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Calculation of flow and loads (rivers, direct point sources)

Water flow is calculated from the automatic measurements of water level and flow measurements in the main hydrological phases.

Riverine loads are calculated as follows:

$$L = \sum_{i=1}^{12} W \, x \, C$$

W – volume of monthly runoff based on daily flow;
C – monthly water concentration (monthly discrete samples)

Data on point sources are obtained from the national data base "Ūdens-2" (Water-2). Pollution loads there are reported by the operators of waste-water treatment plants.

Inputs from unmonitored areas

Areal extrapolation of the monitored load in the upstream or neighbouring catchments.

$L_{unmon} = L_{mon}/A_{mon} * A_{unmon}$,

where: L_{unmon} = unmonitored load (t/y, kg/y)
L_{mon} = monitored load (t/y, kg/y)
A_{mon} = area of the monitored catchment (km^2)
A_{unmon} = area of the unmonitored catchment (km^2)

Source apportionment (load and source oriented approach)

Load oriented approach was used as described in the HELCOM Guidelines for Waterborne Pollution Inputs to the Baltic Sea (chapter 10).
Data on point sources are obtained from the national data base "Ūdens-2" (Water-2). Operators of municipal and industrial wastewater treatment plants and several fish farms have to quantify and report the pollution loads to the data base according to requirements of polluting permits. Sampling frequency of polluting substances varies from one to twelve times per year. Wastewater volume in larger WWTPs are measured by flow meters and it is estimated in smaller WWTPs. Loads by rainwater is partly included the estimation of point sources. The rest is not quantified.

Inputs from scattered dwellings are not quantified.

Export coefficients of Ntot and Ptot from diffuse background sources (forest territories) were obtained from the Latvian State Forest Research Institute "Silava". Export coefficients are then multiplied by the area of forest and wetland in the sub-basin.

Atmospheric deposition on inland fresh water is not estimated.

Retention

Retention was calculated following Behrendt H., Opitz D. (1999) Retention of nutrients in river systems: dependence on specific runoff and hydraulic load. In Man and River Systems (pp. 111-122). Springer Netherlands.

Retention coefficient for nitrogen: R_{SN}=6.3((Q*86,4*0.365)/As$)^{-0.78}$
Retention coefficient for phosphorus: R_{SN}=4,7((Q*86,4*0.365)/As)$^{-0.76}$

where Q is a discharge and area of surface waters in catchment As=A_{lake}+0.001*$A^{1.185}$ (A_{lake} – area of lakes in a catchment, A area of a catchment)
Retention R = $R_{SN,SP}$*Load

Transboundary inputs

For the Rivers Bārta, Venta, Lielupe, and Daugava.

At first, measured monthly concentrations at the border station and extrapolated discharges are used to calculate yearly load coming from a neighbouring country. In the case of the Daugava Rivers, the load is distributed between RU and BY by taking into the account the catchment area in these countries as well as the estimates of retention from the Tables 8.2. and 8.3 in "Guidelines for Waterborne Pollution Inputs to the Baltic Sea".

Uncertainty on flow, loads, unmonitored and total inputs and on sources

In following hydrological stations the uncertainty in flow measurements was estimated to be 7 %: IRBE at VICAKI, BARTA at DUKUPJI. In following hydrological stations the uncertainty in flow measurements was estimated to be 12 %: SALACA at LAGASTE, GAUJA at SIGULDA, DAUGAVA at JEKABPILS, VENTA at VENDZAVA, LIELUPE at MEZOTNE.

Uncertanity of the monitored river load was calculated following Harmel, R.D., Cooper, R.J., Slade, R.M., Haney, R.L., Arnold, J. G. (2006) Cumulative uncertainty in measured streamflow and water quality data for small watersheds. *Transactions of the ASABE*, *49*(3), 689-701.

EP = $\sqrt{\sum(E_Q^2 + E_C^2 + E_{PS}^2 + E_A^2)}$,

where: EP – cumulative uncertainty;

E^2_Q – uncertainty in discharge measurements (±%);

E^2_C – uncertainty in sample collection (grab sampling at single point, random time) ±25% dissolved; >50% suspended constituents);

E^2_{PS} – uncertainty in sample preservation and storage (for N-NO_3 ± 2%, for P_{tot} ± 7%);

E^2_A – uncertainty in laboratory analysis (±%, data from the analytical quality checks of the Laboratory of LEGMC);

Uncertainty of total loads and sources was not estimated.

LITHUANIA

Information provided by Svajunas Plunge (s.plunge@aaa.am.lt)

Calculation of flow and loads (rivers, direct point sources)

Lithuania uses two separate approaches for calculating data required for annual and periodic reporting. Annual flows and loads are calculated from daily river water flow and monthly water quality monitoring data using formulas provided in PLC guidelines. Daily water flow is recalculated to monthly flow averages. Averaged monthly flow and monthly concentrations are used in load calculation (PLC guidelines formula 4.2). All specific details could be observed by examining actual annual load calculation spreadsheet. As it comes to direct point sources, they are few. Yearly data about them are provided by companies or municipalities responsible for those point sources.

For periodic reporting flow and loads are calculated using the SWAT model. The model has been prepared for all Lithuanian territory with the most detailed data available in the country. Model and its preparation and additional alteration are described in the model preparation documentation and the methodological notes for the PLC data preparation.

Inputs from unmonitored areas

Loads and flow from unmonitored areas for annual reporting are calculated using area proportional method described in the guidelines (PLC guidelines formula 7.1). Minija river (neighboring basin to the unmonitored areas) concentrations and flow at the outflow are used together with Minija and unmonitored areas area ratio to calculate loads from unmonitored areas. However, in the periodic reporting modeling approach was used to calculate loads and flows from unmonitored areas.

Source apportionment (load and source oriented approach)

Source apportionment data are prepared using model results. Averaged data for the period of 2007-2014 are provided in reporting in order to cover all period between periodic reportings and avoid extreme deviations of one year biases as year 2014 have particularly low flow and irregular flow distribution during the year. Therefore Lithuanian sources apportionment data represents averaged environmental conditions for last 8 years.

The model is fed with physical data about environment, climate, discharges of point sources, agricultural activities, etc. As the SWAT model is in category of physically based and semi-distributed parameters catchment models, processes occurring in the environment are simulated by the model. All sources apportionment data are based on simulation results. Only atmospheric deposition is calculated using additional deposition data and results are added after aggregating modeling results. The final loads from all the distributed sources were reduced by some percentage to leave final loads the same, but including atmospheric deposition category. This methodology is described in the methodological notes for the PLC data preparation.

Retention

Retention has been calculated using modeling. The routing of pollutants from different sources has been tracked through river network. This allowed calculating retention of all pollutants as well as track pollutants by sources. The SWAT model is based on physical parameters. It simulates processes occurring in the river channel as diffusion, sedimentation, resuspension, break down of pollutants, etc. Thus, total retention is based on simulation of those processes occurring in the river.

Transboundary inputs

Modeling is used to calculate reported transboundary loads and flows needed in the annual and periodic reporting for the exception of loads and flow coming from Belarus. Belarus loads and flow are calculated using monthly concentration and daily flow monitoring data at the border. The calculation is done the same way as for main rivers in the annual reporting (PLC guidelines formula 4.2). Beside modeling and monitoring data, area proportional method is used as well in calculating transboundary loads. Only for Sventoji river transboundary loads and flows coming from Latvia are calculated using area proportional method. This is done because modeling results for the Latvian part of basin were not in line with monitored outflow results. The prepared model does not cover territories of other countries with real input data. Thus, approximations to generate transboundary data does not work well for all modeled rivers.

All data for river basins going to Latvia from Lithuania are modeled. Sesupe loads and flow leaving Lithuanian to Kaliningrad and coming back to Nemunas river are not modeled, but returning loads and flow are increased by area proportional coefficient. Loads and flow leaving Nemunas to Kaliningrad through Matrosovka channel is calculated by flow proportional coefficient, which was calculated from measured Matrosovka flow data. More detailed explanations of model configuration could be found in the model preparation documentation.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainties on flow or loads have not been calculated or reported by Lithuania.

POLAND

Information provided by Weronika Bryńska (weronika.brynska@kzgw.gov.pl)

Calculation of flow and loads (rivers, direct point sources)

Direct Point Sources

- Procedure of calculating loads and flows from point sources has been carried out according to HELCOM Guidelines recommendations.

The methodology of calculating loads from point sources assumes that for each discharge, information about at least one measurement of required parameters and quantity of wastewater were available. Loads are calculated by the following equation:

$$La = 365 \cdot \frac{1}{n} \sum_{i=1}^{n} Q_i \cdot C_i$$

L_a = Annual load

Q_i = Wastewater volume on sampling day [l/day]

C_i = Concentration of the period i [mg/l]

n = Number of sampling days

This algorithm does not take into account the seasonal variability. In this case the results of the estimation may differ from real size.

Based on above method and data from The National Programme for Municipal Waste Water Treatment (KPOŚK), loads (BOD_5, COD, total phosphorus, total nitrogen) from MWWTPs into inland surface waters have been calculated.

Diffuse source

In order to perform load quantification, Poland is divided into 135 subcachments.

For each of 135 subcatchments, total waterborne inputs from diffuse sources entering to the Baltic Sea are obligatory to quantify.

PLC-6 pollution load compilation covers nitrogen and phosphorus loads from following diffuse source:

- Agricultural land;
- Forestry and other unmanaged land
- Scattered dwellings;
- Storm water and overflow;
- Atmospheric deposition directly on inland surface waters

Agricultural land

In order to calculate nutrient losses from agricultural land for each of 135 subcatchments, following steps have been taken:

1. Monitoring points for each mini-catchment have been selected and annual average nitrates/phosphates concentration was calculated
2. Agricultural land for each mini-catchment was estimated
3. Annual water outflow from mini-catchments was estimated and part of outflow coming from agriculture was calculated.

The quantification of nutrient losses from agricultural land into surface waters, was carried out based on concentration of nutrients in drainage water, at 1500 monitoring points. The samples of nutrient concentration in drainage water were taken two times per year (in spring and autumn).

The first step was to calculate subcatchment load based on nitrate/phosphate concentration and outflow from subcatchment. As a result, mineral part of nitrogen (phosphorus) in surface water was received.

$$L_{r(N,P)} = m \cdot C_{Wr(N,P)} \cdot Q_z$$

$L_{r\,(N,P)}$- Phosphorus(P) or nitrogen(N) discharge to water body (kg/a)

$Cw_{r\,(N,P)}$ – average nitrate (phosphate) concentration (mg/l) in outflow.

Q_z – average flow in subcatchment (l/(s*km^2))

M - unit conversion coefficient - 0.31536

To obtain more reliable data, it was necessary to estimate correction factor $Z_{N,P}$, which takes into account nutrient loads from other nitrogen (phosphorus) compounds. $Z_{N,P}$ was calculated as:

$$Z_N = \frac{\overline{C}_{Ntotal}}{\overline{C}_{NNO3}} \quad ; \qquad Z_P = \frac{\overline{C}_{Ptotal}}{\overline{C}_{PPO4}}$$

Total loads of total nitrogen(Lr_{Nog}) and total phosphorus(Lr_{Pog}) are calculated as:

$$L_{rNog} = Z_N \cdot L_{rN} \cdot A_r \quad ; \qquad L_{rPog} = Z_P \cdot L_{rP} \cdot A_r$$

L_{rN} - estimated nitrogen load (kg/(ha*a))

L_{rP} - estimated phosphorus load (kg/(ha*a))

Z_N - nitrogen correction factor

Z_P - phosphorus correction factor

A_r - area of agricultural land (ha)

Forestry and other unmanaged land.

Spatial resolution of loads from managed forestry and other managed land depends on slope of the land average slopes within the catchment area and permeability of soils. To calculate nitrogen and phosphorus loads, adjusting average slope, and predominant category of soil permeability for each catchment area, was needed. Thus, nitrogen and phosphorus content in precipitation and flow weighted concentration from managed forestry has been verified.

Specific nutrient load from managed forestry and other managed land was calculated by applying the following equation:

$$L_{t(N,P)} = m \cdot C_{Wt(N,P)} \cdot Q_z$$

L_t - individual nitrogen (phosphorus) load (kg/(ha*a))

Cw_t - flow weighted concentration of period t (mg/l)

Q_z - average outflow volume in a given period t (l/(s*km^2))

M - unit conversion coefficient - 0.31536

The average slope within the catchment area	**Permeability of soils**	**Flow weighted concentration Cw_t**	
		nitrogen mgN/l	**phosphorus mgP/l**
Slope ≤ 2%	good	**0,31**	**0,038**
	average	**0,75**	**0,038**
	bad	**1,09**	**0,038**
Slope > 2%	good	**0,31**	**0,038**
	average	**0,75**	**0,038**
	bad	**1,22**	**0,038**

Total loads of total nitrogen (Lt_{Nog}) and total phosphorus (Lt_{Pog}) are calculated as:

$$L_{tN} = L_{tN} \cdot A_t \quad ; \qquad L_{tP} = L_{tP} \cdot A_t$$

L_{tN} *-the nitrogen load in water outflow kg/(ha*a)*

L_{tP} *- the phosphorus load in water outflow kg/(ha*a)*

A_t - catchment area used (ha)

Scattered dwelling:

Nutrient losses from scattered dwelling was defined based on the data from Central Statistical Office of Poland, referring to the households not connected to the municipal sewage systems.

Assuming that average nitrogen/phosphorus load, produced by single person is 4.4 kg N/a and 0.8 kg P/a, load could be quantified as follows:

$$L_l = N_s \cdot l_{N,P} \cdot B$$

L_l - load from scattered dwelling (kg/a)

N_s -population not connected to sewage system

$l_{N,P}$ - average nitrogen/phosphorus load, produced by single person (kg/a)

B - coefficient related to load entering inland surface waters (0,4-N, 0,2-P - according to HARP guidelines)

Rainwater constructions and overflows

Quantification of nutrient losses from rainwater constructions and overflows has been carried out according to HARP, 2000 guidelines. The total nitrogen and phosphorus discharges from the separate sewer system may be estimated by the following equation:

$$L_{dN,P} = A_u \cdot d_{N,P}$$

$L_{dN,P}$ -the total nitrogen and phosphorus discharges from combined sewer overflows (kg/a)

A_u - sealed urban area connected to combined sewer system (ha)

$d_{N,P}$ -specific nitrogen and phosphorus discharges from sealed urban area (kg/ha*a)

Calculated for Poland average specific nitrogen and phosphorus discharges by separate sewer systems in 2011 were d_N = 14 kg N/ha for nitrogen and d_P = 1.2 kg P/ha for phosphorus.

Atmospheric deposition on inland surface waters

In order to estimate nutrient losses from atmospheric deposition, data from chemistry of precipitation monitoring and CORINE Land Cover have been used. The calculation method assumes that total nitrogen and phosphorus content in the precipitation enters inland surface waters.

$$Lo_{N,P} = S_w \cdot qs_{N,P}$$

$L_{ON,P}$ - nutrient load from atmospheric deposition on inland surface waters (t/a)

S_w - sum of surface waters in catchment (km^2) according to CORINE Land Cover

$q_{sN,P}$ - annual area specific nitrogen/phosphorus load (kg/km^2)

Inputs from unmonitored areas

Recommended method form PLC-6 Guidelines has been used. Load has been estimated according:

$$L_n = L_m \frac{A_n}{A_m}$$

L_n	Load from unmonitored area A_n
L_m	Known load coming from monitored area A_m
A_n	Area of unmonitored hydrological basin
A_m	Area of monitored hydrological basin

Source apportionment

Source apportionment has been carried out according to PLC guidelines.

The source apportionment was made by a summary of discharges from point sources and diffuse sources and then the percentage of various sources of pollution in the total discharge charge has been calculated. The riverine load has been calculated according to source apportionment.

Retention

Retention in accordance with requirements of PLC Guidelines- Horst Behrendt & Dieter Optiz Method.

Transboundary inputs

Transboundary loads has been calculated based on measurements of State Environmental Monitoring at monitoring points. Where it was possible, an average flow rate of 2012 has been used, in other cases the flow rate of the long term annual averages.

$$La = C_{śr} \cdot Q_{śr} \cdot W_j$$

La	- annual load t/a
$C_{śr}$	- average sample concentration mg/l
$Q_{śr}$	- average volume m^3/s
W_j	- coefficient (3600s*24h*366days or 365days)/1000000

Uncertainty on flow, loads unmonitored areas and total inputs on sources

Uncertainty are not estimated.

RUSSIA

Information provided by Natalia Oblomkova (oblomkova@helcom.ru, oblomkovan@gmail.com)

In general, Russia follows the methodology described in the PLC-6 guidelines.

Calculation of flow and loads (rivers, direct point sources)

The annual monitored river discharges for nutrients were calculated by multiplying the monthly concentration by the monthly flow and summing up the monthly loads (equation 4.2 from the PLC-6 Guideline). Initial data (flow and concentrations values) provided within state monitoring. In some cases, due to lackof the mandatory parameters in the in the monitoring programme specific estimates have been used (total nitrogen and phosphorous have never not been monitored in the the Pregolya river within state programme – in this case concentrations , obtained from the BASE Project monitoring activities and the actual flow value for 2014, were used to calculate loads Loads of some heavy metals (Hg for Gulf of Finland rivers; Pb and Cd for Pregolya river) haven't been calculated due to lack of measurements in the monitoring programme.

Direct point sources load obtained from the state statistical reporting, based on the continuous measurements implemented by nature users.

Inputs from unmonitored areas

Estimation of the nutrient pollution from unmonitored areas has been implemented using Institute of Limnology Loading Model (detailed description provided below).

Source apportionment (load and source oriented approach)

Source apportionment implemented using Institute of Limnology Loading Model by parts of sub-catchments (e.g. Luga river, Ladoga Lake catchment, Peipsi Lake catchment, small rivers of the Northern part of the Gulf of Finland catchment.

The basic components of the total annual load on catchment (Ltot) of Ptot and Ntot are the loads from point sources (Lp), diffuse load from agricultural production in the area (Lagr), diffuse emission of nutrients from various types of land surface not effected by agriculture (Le), atmospheric deposition (La):

$$L = \left(L_{agr} + L_c + L_{P1} + L_a\right), \qquad (1)$$

The point sources include the discharges of sewage waters of the industrial, agricultural and municipal enterprises. The official source of data on sewage discharges are state statistical forms ("2TPVodhoz").

The diffuse load on catchment from the emission of nutrients from various types of land surface (natural and anthropogenic) excluding agricultural areas Lc is calculated as follows:

Lc = (Cu Au + Cnat Anat + Cmix Amix) y/1000, (2)

where Cu, Cnat and Cmix are the specific concentrations of nutrients in runoff from urban areas, the natural land surface and mixed areas, accordingly [mg l -1],

Au, Anat and Amix are the areas of the mentioned types, respectively, of a land surface [km^2], y is a runoff from the catchment [mm $year^{-1}$].

Urban areas represent the input from sparse population that is not connected to sewer networks and treatment facilities. Values of *y* from the whole catchment or its parts can be taken from measurements or calculated using distribution functions or using a hydrological model.

Kondratyev (2007) reported that the phosphorus load from atmospheric depositions (La = da A) ranges from 0.002 to 0.005 t km^{-2} y^{-1}. Here, a value of 0.0032 t km^{-2} y^{-1} was used. Value La for nitrogen load is zero, if it is assumed that nitrogen deposition from the atmosphere (loss with deposits + fixed by biota) equals removal by denitrification (Behrendt, Dannowski, 2007).

Nutrient load, generated on agricultural areas, calculated based on the method proposed by Institute of Institute for Engineering and Environmental Problems in Agricultural Production (Saint-Petersburg, Russia). It is possible to calculate loads on receiving water bodies from the particular field, farm or district. The method is fitted for North-West region of Russia conditions and based on following equation:

$$L_{agr} = \sum_{i=1}^{n_1} A_i \left(M_{soil\,i} K_1 + (\alpha_1 M_{\min i} + \alpha_2 M_{org\,i}) K_6\right) K_2 K_3 K_4 K_5 / 1000 \quad , \tag{3}$$

where M soil i , M min i and M org i – N and P content in the plough layer, as well as amount of organic and mineral fertilizer applied on field, owned by i agricultural enterprise, kg/ha;

Ai – field area, owned by i agricultural enterprise, ha; n1 – number of agricultural enterprises;

α1 – coefficient, related to the uptake of mineral fertilizer by crops;

α2 – coefficient, related to the uptake of organic fertilizer by crops;

K1 – coefficient describing nutrients outflow from plough;

K2 – coefficient describing distance of agricultural areas from receiving water bodies;;

K3 – coefficient for soils type (by origin);

K4 – coefficient describing soil texture;

K5 – coefficient for accounting land use structure;

K6 – coefficient for describing status of applying BAT for application mineral and organic fertilizer by agricultural enterprises.

Farm level calculations were performed for coastal catchments of the Gulf of Finland. For upper parts of the catchments average data by municipal districts was used.

Background (natural) load component [t y^{-1}] is a part of the non-point nutrient load calculated as follows:

Lnat = Rt [da A + yCnatA (1-W/100)/1000] *(4)*

where *da* – coefficient for mass exchange with atmosphere;

W – share of lake area in percentage;

Rt – retention factor.

Retention

For calculation of the discharge of Ptot and Ntot from the catchment and loading on water body L [tons $year^{-1}$] the following equation is used (Behrendt, Opitz, 1999):

L=Rt Ltot+Ldirect = (1-Rr) Ltot +Ldirect =Ltot-Lret+Ldirect, (5)

where Rt and Rr are dimensionless factors of discharge and retention, Ltot is the nutrient load on catchment [t y-1], Lret is the retention by catchment (Lret = Rr Ltot) [t y-1], Ldirect – direct load on water body [t y-1].

$$R_r = k_{cal}(1 - \frac{1}{1 + aHL^b}), \qquad (6)$$

Value of the hydraulic load HL is proportional to the specific runoff q [dm3 km^{-2} sec^{-1}] and inversely proportional to the lake percentage W [% of catchment total area]:

HL=3.15q/W. (7)

The specific runoff q [dm3 km^{-2} s^{-1}] is determined with the runoff y [mm $year^{-1}$] as follows

q = 0.03171 y. (8)

Transboundary inputs

Transboundary load has been defined based on shares and methods used in PLC 5.5 Project and actual monitoring data for 2014.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

Uncertainty of total loads and sources has not been estimated

References:
1. BaltHazAR II project, Component 2.2: Building capacity within environmental monitoring to produce pollution load data from different sources for e.g. HELCOM pollution load compilations. Modeling the Luga river.
2. Behrendt H., Dannowski R. Nutrients and heavy metals in the Odra River System. - Weissensee Verlag Publ., Germany, 2007, 337 p.
3. Behrendt H., Opitz D. Retention of nutrients in river systems: dependence on specific runoff and hydraulic load. - Hydrobiologia, 1999, 410: 111-122.
4. Kondratyev S.A., 2007: Formirovanie vneshney nagruzki na vodoemy: problemy modelirovaniia (Formation of external loading on water bodies: problems of modeling). Nauka, St. Petersburg, 255 p, (in Russian).
5. To develop method and calculate nitrogen and phosphorous load originate from agricultural production activities in the catchment as well potential reduction when applying BAT (In Russian: Разработать методику и выполнить расчет диффузной нагрузки азота, фосфора на водосбор при ведении сельскохозяйственной деятельности и потенциала ее снижения при использовании НДТ в сельском хозяйстве). Report about scientific and research work, IEEP RAS, 2015, 22 p.
6. To implement scientifically grounded assessment for sources appointment of nutrient input from river catchments within Russian part of the Baltic Sea catchment in 2014 (In Russian: Выполнить научно-обоснованную оценку долевого вклада всех источников в формирование в 2014 г. фактической биогенной нагрузки на водосборных бассейнах рек, впадающих в Балтийское море с российской части водосборного бассейна), Report about scientific and research work, RSHU, 2016.

Sweden

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Calculation of flow and loads (rivers, direct point sources)

Daily water flow and monthly concentrations (interpolated to daily concentrations) are used to calculate the monthly and annual loads for the 43 monitoring stations included in the national monitoring programme on river mouths. These monitoring stations are to some degree supported by other national and regional monitoring sites to support the estimation of loads from unmonitored areas.

Point sources

Wastewater treatment plants with more than 200 person equivalents (p.e.) and industries are monitored at the facilities on regular bases by the facility owners. As part of the authorities control the facility owner are obliged to report the data to the Swedish Portal for Environmental Reporting (SMP). The facility owner report the annual loads and the data reported are based on this data. Fish farms also report load data to SMP, these data are typically estimated by the facility owner from the fish feed consumption and annual growth of the fish population

Smaller wastewater treatment plants with less than 200 person equivalents (p.e.) are not obliged to report their data to the authorities, therefor the load is estimated by multiplying the number of p.e. and a coefficient that is based on the treatment technic used. The coefficient and the estimated incoming nutrient content are adjusted to Swedish conditions.

1 PE is for N=13.7 g/day and for P=1.7 g/day which is combined with an removal in the WWTP according to the table below:

Treatment method	Removal of phosphorus [%]	Removal of nitrogen [%]
Biological or field based treatment	35	40
Chemical treatment	88	33
Chemical and field based treaqtment	91	54
Biological and chemical treatment	92	42
Biological, chemical and filtration	97	42
Biological, chemical and field based treatment	97	49
Biological, chemical and extra N removal	99	76

Inputs from unmonitored areas

For minor river systems that do not have any national monitoring site in the lower parts of the rivers the loads are estimated with the area-specific load from other similar rivers in the area.

The load from unmonitored areas downstream monitoring sites are quantified by the area specific loss from the monitored parts, and the loads are included in the amounts given for the monitored areas. Generally, the monitored parts of the rivers cover some 95-100% of the total areas. Though, there are some exceptions like Rönneån where the monitoring station covers only 51 % of the total area. In addition to the area-specific load from the upper monitored area, the load from the unmonitored area is also estimated with the weighted area-specific load from other similar rivers in the area as the lower stretches are contain more farmland compared to the forested upper part of the catchment area.

Source apportionment (load and source oriented approach)

The Source oriented approach.

The load of nutrients (nitrogen and phosphorus) to lakes and rivers has been calculated for about 23100 Swedish WFD water body catchments, average size 11 km^2. The general system approach is described in Brandt et al (2009), but several of the models and data included have been developed or exchanged since PLC5, as briefly described below. The load comes from point sources (wastewater treatment plants, industries, and fish plants) and from diffuse pollution (land use leaching, storm water, scattered dwellings, and the deposition on lakes). Land use leakage within a catchment is calculated by land use area (km^2) multiplied by runoff ($l/s/km^2$) and a specific concentration describing leakage concentration in runoff water for the current land use (mg/l). Atmosphere deposition on land surface is included in the specific concentration land use leakage.

Daily mean runoff has been simulated using the HYPE model in about 37 000 subcatchment for year 2014. Based on the daily runoff, yearly and monthly average values have been calculated. The load is calculated specifically for year 2014 (crop area, land use area, point source load, runoff).

The specific concentrations for nitrogen and phosphorus leaching from agricultural land have been calculated using the NLeCCS system. NLeCCS, which is a system for calculating normal leakage from arable land, includes the simulation tools SOILNDB (based on SOIL / SOILN models) for nitrogen and ICECREAMDB (based on the ICECREAM model) for phosphorus. NLeCCS system takes into account the most important factors (both farming methods and natural endowments) that affect the leaching of nutrients from agricultural land. Simulation input data regard fertilization, manuring, atmospheric deposition, crop yield, catch crops, protection zones, agricultural practice, climate data, crop rotations, crops, soil type, soil phosphorous, soil slope.

Specific concentrations from land use of forest, clearcut forest, wetlands, alpine and other open land use is based on data from representative areas within the regional and national monitoring programs and on data from new targeted monitoring campaigns in Southern Sweden carried out after PLC5. The specific concentrations are based on data from streams.

Storm water surface runoff coefficients and specific concentrations of urban land use comes from the database of the StormTac model. The specific concentrations were geographically adjusted using weighting by the deposition rate of nitrogen.

Diffuse load from scattered dwellings was calculated using the number of population not connected to wastewater treatment plants, load per person, reduction efficiencies of techniques and municipal information of the techniques used.

Deposition of nitrogen on lake surfaces is based on calculations using the MATCH model and assimilated data, while the deposition of phosphorus is a median value for all of Sweden based on monitoring data.

Point source load is calculated based on direct measurements at the facility (including data reported to the Swedish Portal for Environmental Reporting, SMP). Load from small point sources of wastewater treatment facilities are calculated based on loads with regard to other data such as type of treatment technology and number of persons equivalents connected and load per person.

The load oriented approach.
The net load to the sea is calculated with retention modelled using the SMED-HYPE model for all 23,100 catchments. The total source apportioned load calculated to the river mouths was weighted to the total PLC annual river load reported in monitored and unmonitored rivers, and all sources were adjusted according to the weight.

The major differences in method and data from PLC-5 to PLC-6 is the use of new, high resolution land-use and soil type maps, new data concerning purification in off-mains sewerage and storm water as well as a new elevation database (with 2 m horizontal resolution). The elevation database has been used to calculate slope steepness, which is of great importance for estimates of phosphorus leakage. New monitoring observations in forest areas in southwestern Sweden have provided a better understanding of nutrient leakage in woodland areas and a new nutrient retention model has been developed as a result. The runoff has been calculated with a new model HYPE and the retention has been calculated using the new SMED-HYPE model.

Retention

The retention from source to sea was calculated using the SMED- HYPE model in all 23,100 WFD water body catchments. SMED-HYPE retention builds upon the HYPE-model (Lindström et al 2010). In lakes and rivers, the nutrient processes are described similarly in both HYPE and SMED-HYPE. The major differences are the model description of the land use leakage (SMED_HYPE land use leakage described in the source-oriented approach above) and the local river retention. Internal load from the lake sediments (negative retention) was reported for lakes where the mass balance was supported by inlet to outlet monitoring data.

Reference:
Lindström, G., Pers, C.P., Rosberg, R., Strömqvist, J., Arheimer, B. 2010. Development and test of the HYPE (Hydrological Predictions for the Environment) model – A water quality model for different spatial scales. Hydrology Research 41.3-4:295-319.

Transboundary inputs

Swedish catchments do not contribute to any significant transboundary output to the neighbouring countries. The load from Norwegian and Finnish catchments contributing to

Swedish catchment was calculated using Corine LandCover as land use representation, thus not including anthropogenic land use sources. Point source loads were delivered from Finland to Sweden to be able to calculate retention in Torne river more correctly. Transboundary load was not reported by Sweden in PLC-6. Additional calculations are currently being performed to better represent the transboundary anthropogenic sources contributing from Norway and Finland to Swedish catchments.

Uncertainty on flow, loads, unmonitored and total inputs and on sources

The uncertainty of sources has large variations due to the different underlying data and model performances. The uncertainty has not been reported for sources by Sweden for the PLC-6.