Daily Allowable Maximum Loads to decrease nutrient load to the Gulf of Riga (DAML)
Report of the Activity T1.1

Development, testing and promotion of a novel methodology for Estimation of Daily Allowable Maximum Loads (DAML) of pollutants to decrease nutrient load to the Gulf of Riga

Methodology

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1. Introduction

One of the aims of the Interreg Estonia-Latvia project „Daily Allowable Maximum Loads to decrease nutrient load to the Gulf of Riga" is to develop and test a methodology for assessment of required and possible reduction of nitrogen and phosphorus riverine loads which accounts for the variability of water quality associated with different stream flow rates. It requires respective analysis and evaluation of the maximum allowable daily loads of pollutants (DAML). Thus, development of DAML is an essential step for recovering of the water quality in streams as well as in receiving lakes and the sea and achieving of the quality criteria set for the water bodies.

The HELCOM proposed the Baltic Sea Action Plan to restore the good ecological status of the Baltic marine environment by 2021 and agreed upon the nutrient reduction scheme, including Maximum Allowable Inputs of nutrients and Country-Allocated Reduction Targets to reduce nutrient inputs (HELCOM, 2013) . The water quality standards are set on national level and every member state is responible for evaluation of the possibilities for further decrease of riverine nutrient load where it would be more realistic and cost-effective.

The DAML is the maximum amount of cumulative N and/or P loading (kg/tons per day) from different sources acceptable for the specific river without exceeding quality standards and the buffering capacity of the stream, or for achieving water management targets.

The methodology is based on the application of the flow duration curve and the streamflow exceedance probability curve (EPA, 1991 and 2007). The streamflow exceedance probability curve shows the parameter value (e.g. flow as well as pollution load) that is likely equal or exceeds some specified value of interest. The data graph can easily be developed based on the monitoring results of discharge and the content of nitrogen and phosphorus in a studied stream. Long-term daily median discharge rates and at least 5 years content of pollutants and daily runoff of pollutants is analysed to maintain homogenity of the monitoring data.

2. Needed steps to estimate the DAML

Three steps are needed to estimate the Daily Allowable Maximum Loads:

1. **Development of the flow duration curve and analysis.**

Chronological record of daily discharge values will be ranked from the largest to the smallest (Table 1). P describe probabilirty of occurance of the discharge.

Table 1. Daily discharges in 1992 to 2019.

Rank	AVIJÕGI	Decreasing order	
r(1-8957)	Date	Q, m3/s	P %
1	4/12/1999	43,6	0,011169
2	4/11/1999	41	0,022339
3	4/10/2011	38	0,033508
4	4/9/2011	35,8	0,044678
5	4/13/1999	34,5	0,055847
6	3/29/2012	33,4	0,067017
7	4/8/2010	32,8	0,078186
8	4/18/2013	32,8	0,089356
9	3/28/2012	32,3	0,100525
10	4/8/2011	32,1	0,111694
11	4/17/2013	31,9	0,122864
12	4/8/2009	31,8	0,134033
13	4/8/1994	31,6	0,145203
14	4/9/1994	31,2	0,156372
15	4/11/2011	30,6	0,167542
16	4/10/1999	30,4	0,178711
17	4/12/2010	30,4	0,18988
18	4/11/2010	29,9	0,20105
19	4/7/2009	29,8	0,212219
20	4/9/2010	29,8	0,223389
21	11/21/2016	29,5	0,234558
22	4/10/2010	29,3	0,245728
23	4/13/2010	29,3	0,256897
…	…		
…	…		
…	…		
…	…		
8947	9/21/1999	0,2	99,93298
8948	9/22/1999	0,2	99,94415
8949	9/23/1999	0,2	99,95532
8950	9/20/1999	0,19	99,96649
8951	9/6/1999	0,18	99,97766
8952	9/7/1999	0,18	99,98883
…			
…			
…			

The flow exceedance probability curve can be designed based on this data. The discharge is given on the vertical axis and exceedence frequency is given on the horizontal axis (Fig. 1). Calculate the percent of time (days) that each discharge is equaled or exceeded a specified value of interest (ranging between 0 and 100).

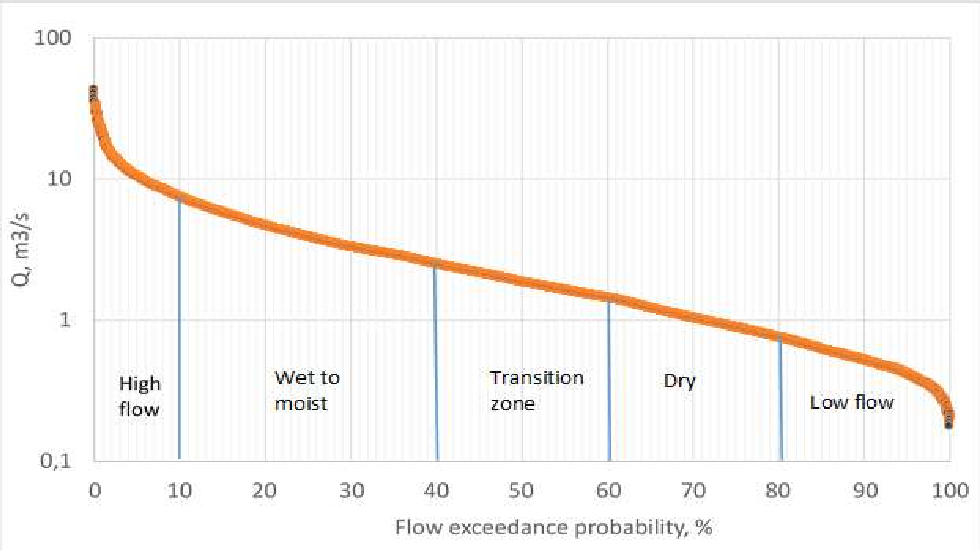


Figure 1. The flow exceedance probability curve and and discharge zones of the River Avijõgi 1992-2016.

The exceedence frequency zero corresponds to the highest discharge in the record (i.e. flood conditions) and 100 to the lowest (i.e. drought conditions).

The midpoints of the moist, mid-range and dry zones are at the 25th, 50th, and 75th percentiles respectively (i.e., the quartiles). The midpoint for high zone (0-10%) is at the 5th percentile, and the low zone (90-100%) at the 95th percentile. Definition of high and low zones can be changed (e.g. 0-20% and 80-100%, respectively, as on Figure 1)

The exceedence probability can be calculated as:

$$P(\%) = (m / n+1) * 100, \text{ where}$$

P = the probability that a given flow will be equaled or exceeded (% of time)
m = the ranked position on the listing
n = the number of events for period of record

2. **Calculation of Daily Allowable Maximum Loads (DAML) of pollutants (e.g. P and N).**

Maximum allowed concentration (water quality target) of N or P (e.g. N<2 mg/l or P<0,05 mg/l) multiplied by discharge to get e.g. maximum allowed daily load of compounds (L= C x Q) (Table 2):

N load (DAML, kgN/day) = discharge Q l/s * 2 g/m^3
P load (DAML, kgP/day) = discharge Q l/s * 0,05 g/m^3

Table 2. Calculation of MAL and observed load.

Rank	AVIJÕGI	Decreasing order			MAL kg/d	0bserved kg/d
r(1-8957)	Kuupäev/date	Q, m3/s	Püld mg/l	P %	0,05 mg/l	Ptot
1	1999-04-12	43,6		0,011169	188,352	
2	1999-04-11	41		0,022339	177,12	
3	2011-04-10	38		0,033508	164,16	
4	2011-04-09	35,8		0,044678	154,656	
5	1999-04-13	34,5		0,055847	149,04	
6	2012-03-29	33,4		0,067017	144,288	
7	2010-04-08	32,8		0,078186	141,696	
8	2013-04-18	32,8		0,089356	141,696	
9	2012-03-28	32,3		0,100525	139,536	
10	2011-04-08	32,1	0,075	0,111694	138,672	208,008
11	2013-04-17	31,9		0,122864	137,808	
12	2009-04-08	31,8		0,134033	137,376	
13	1994-04-08	31,6		0,145203	136,512	
14	1994-04-09	31,2		0,156372	134,784	
15	2011-04-11	30,6		0,167542	132,192	
16	1999-04-10	30,4		0,178711	131,328	
17	2010-04-12	30,4	0,041	0,18988	131,328	107,689
18	2010-04-11	29,9		0,20105	129,168	
19	2009-04-07	29,8		0,212219	128,736	
20	2010-04-09	29,8		0,223389	128,736	
21	2016-11-21	29,5		0,234558	127,44	
22	2010-04-10	29,3		0,245728	126,576	
23	2010-04-13	29,3		0,256897	126,576	
…	…	…		…	…	…
…	…	…		…	…	…
…	…	…		…	…	…
…	…	…		…	…	…
8947	1999-09-21	0,2		99,93298	0,864	
8948	1999-09-22	0,2		99,94415	0,864	
8949	1999-09-23	0,2		99,95532	0,864	
8950	1999-09-20	0,19	0,01	99,96649	0,8208	0,16416
8951	1999-09-06	0,18		99,97766	0,7776	
8952	1999-09-07	0,18		99,98883	0,7776	

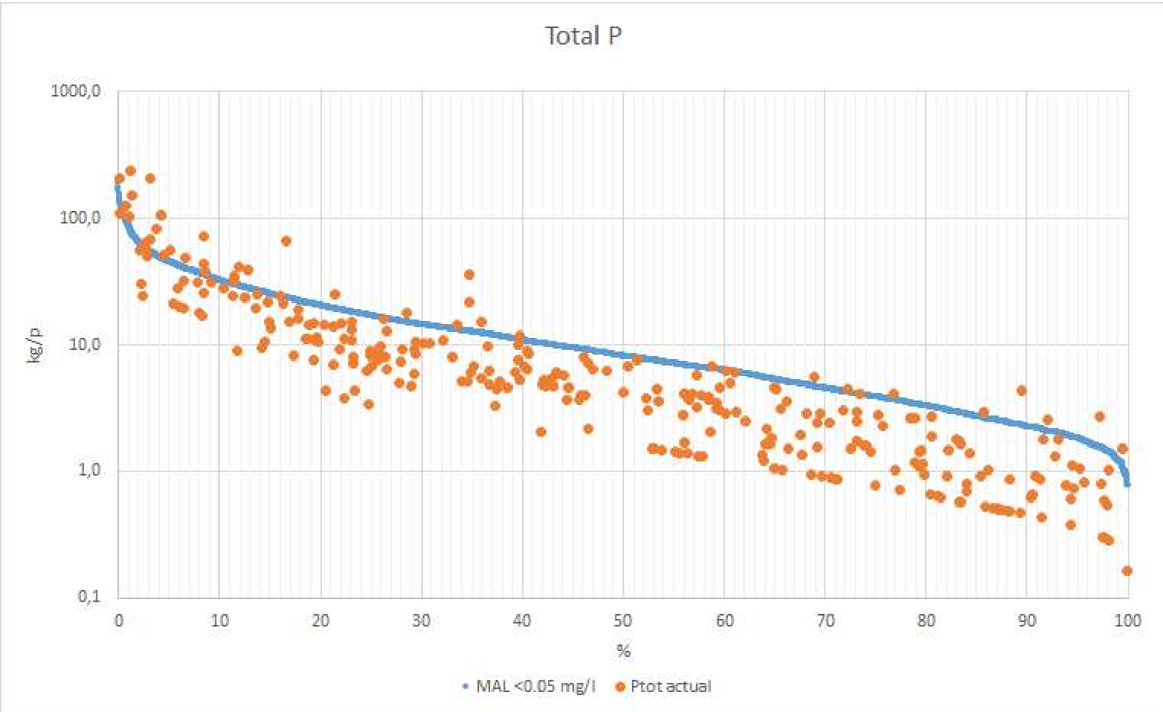
Definition of maximum allowed concentrations could be based on the levels defined for the streams e.g. within the WFD.

The target is usually constant across all flow conditions (loads are directly proportional to flows). Theoretically it is possible to apply varying targets depending on the flow and knowing that the water quality parameters are often related to stream flow rates (e.g., sediments, nitrogen, dilution).

3. Comparison of water quality data with the nutrient runoff duration curve.

Actual instantaneous loads calculated from ambient water quality data with some measure or estimate of flow at the time of sampling at station X will be compared with the Daily Allowable Maximum Load (DAML) of a compound during the same day at station X. Thus, it will be possible to calculate the percentage of time (days) that each concentration/load is equalled or exceeded the flow duration curve value. Loads above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show compliance.

The results will be expressed by a curve where vertical axes is the daily pollution load (kg/d or t/day) and horizontal axis is the percentage of exceedances of load (Fig. 2).



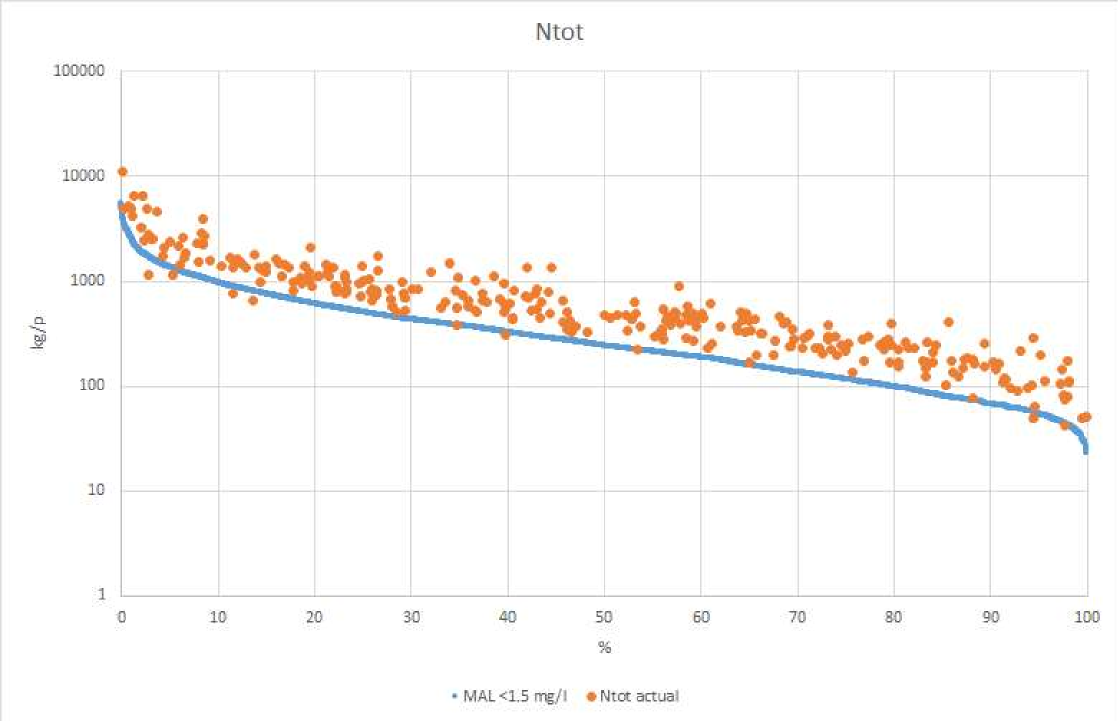


Figure 2. Comparison of water quality data with the flow duration curve (DAML) (Loitme, 2020)

3. Interpretation of the results

Loads with the exceedance frequency 85 to 100% are characteristic for the low flow perioods, likely permanent input from point sources, insufficient handling of wastewater, poor dilution with natural water, etc.

The exceedance probability 0-10 % is characterise high flow period, floodings and extreme hydrological conditions. Exceedances during high flow periods generally reflect potential impact from nonpoint sources.

The exceedance probablity between 10-40% reflect moist to wet period and more saturated soil conditions with prevailing anaerobic biodegradation and transport of degradation compounds to rivers. The flow exceedance probability between 60-80 %, reflect dry period and aerobic conditions in soils. The exceedance probability between 40-60% is a transition zone between moist and wet conditions (Fig. 3).

More straight line of the exceedance probability curve in the middle zones indicates less extreme flows and regulated water flow while unregulated system has larger variabilty of flow .

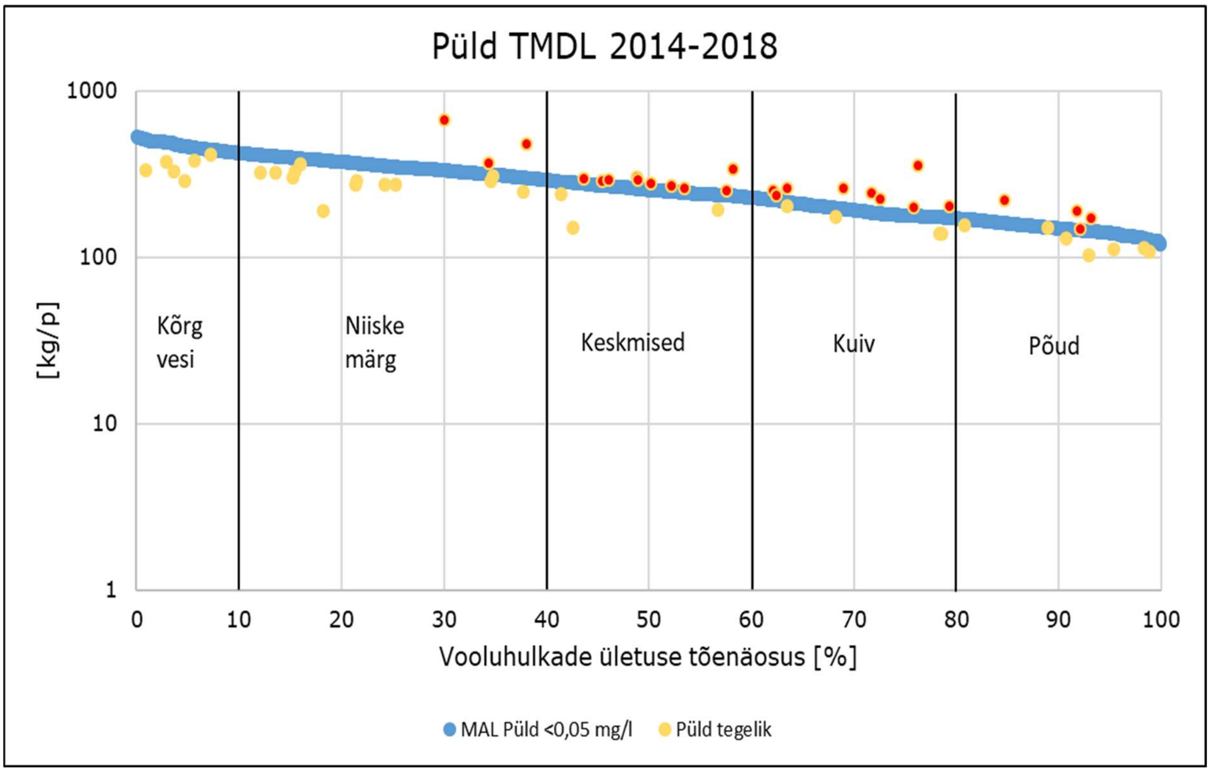


Figure 3. Actual and allowable total phosphoprous loads during diferent flow duration intervals in the river Emaiõe/Kavastu station in 2014-2018 (Loitme. 2020)

The results can be expressed in table (e.g. Table 3) as well as graphically (Fig. 4).

Table 3. P_{tot} load compared to DAML

Flow exceedance probability	No of samples	Median daily discharge	Observed load	DAML (Ptot =0,05 mg/l)	Difference,	Reducion or surplus
%	Total 59	m^3/s	kg/d	kg/d	kg/d	%
0-10	6	658.6	2123	2845	-722	-25.4
10-20	6	550.5	1826	2378	-505	-21.2
20-30	4	332.9	1107	1438	-303	-21.1
30-40	6	434.7	2354	1878	437	23.3
40-50	7	438.7	1847	1895	-44	-2.3
50-60	6	336.1	1582	1452	118	8.1
60-70	6	292.1	1375	1262	103	8.2
70-80	7	287.7	1495	1243	231	18,6

80-90	3	111.3	525	481	41	8.5
90-100	8	259.3	1077	1120	-40	-3.6

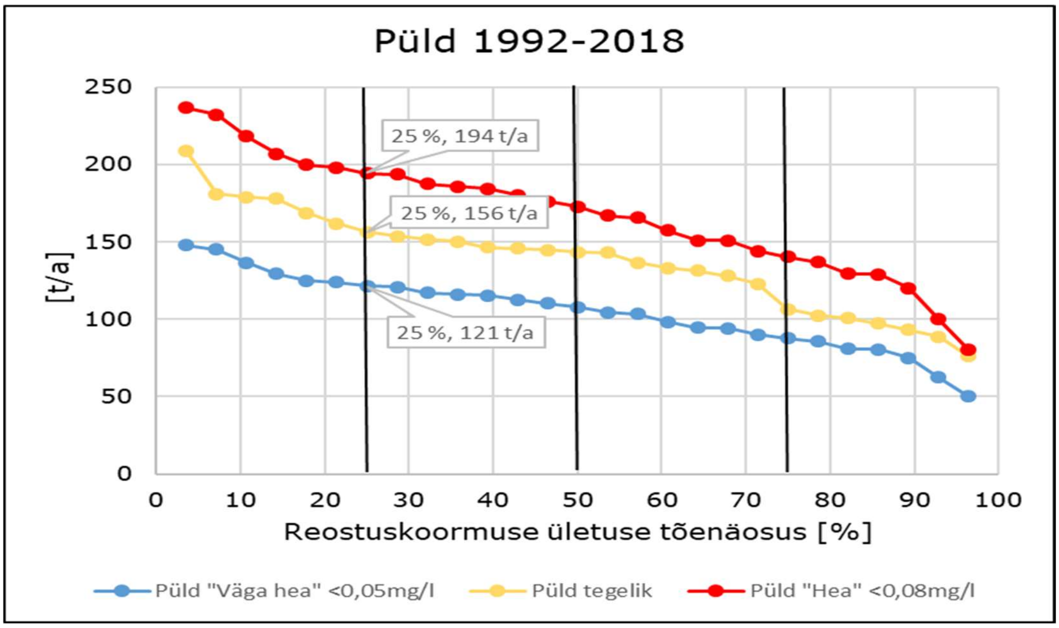


Figure 4. Comparison of actual Ptot load with the load of achieved water quality targets (Loitme, 2020)

Thus, DAML provide information for allocation of pollution load (i.e. point source pollution, storm flows and diffuse pollution, natural background load).

- DAML could be used as a tool for source apportionment considering seasonal variability and defined national targets.
- Additional analysis in the watershed to define possible sources for reduction is needed if it appears that DAML does not allow achieving of the requirements set for the surface waters.

Allocations can be adjusted by flow duration zone that allow accounting of load from different source areas and delivery mechanisms under different flow conditions.

4. Data requirements

For testing of DAML:

1. Long-term daily flow for selected rivers (incl. subwatersheds for larger catchments).
2. Monthly water chemistry data.
3. Desired water quality target.

For allocation of pollution load:

1. Landuse and landcover data for selected watersheds (subwatersheds).
2. Point source load data.
3. Area specific runoff values for N and P (or modelling outputs) for agricultural land, natural background areas
4. Precipitation data
5. Soil type, occurance of karst phenomenon, etc.

6. Conclusions

- The DAML tool can be used for estimation of allowable loads of compounds and allocation of these loads to the pollutant sources in the watershed. This information could provide a basis for application of suitable measures to control pollution load and achieving the good status of waterbodies.

- The flow duration curve is more appropriate if pollution load is mainly driven by discharge and other processes are relatively insignificant.

- Individual sources and relative contributions of pollution sources can´t be precisely tracked by the DAML method. Therefore, application of additional methods (e.g. modelling, separation of base-flow and surface runoff, etc.) is needed.

- Larger watersheds with varying landuses and pollution sources require application of the DAML method in subwatersheds.

Literature

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