8. Load Assessment

8.1 Introduction

One of the main objectives of TNMN is to produce reliable and consistent trend analysis of concentrations and loads of substances diluted in water or attached to sediments. Load assessment in the Danube River is necessary to estimate the influx of polluting substances to the Black Sea and to provide an information basis for both policy development and assessment.

Within the framework of EU PHARE Project "Transboundary Assessment of Pollution Loads and Trends", a Standard Operational Procedure (SOP) was developed for load assessment. The countries agreed to use this SOP as a common and cost-effective approach for load assessment in the Danube River and its tributaries.

8.2 Description of load assessment procedure

MLIM EG has agreed the following principles for the load assessment procedure:

- load is calculated for the following determinands: BOD_5, inorganic nitrogen, ortho-phosphate-phosphorus, dissolved phosphorus, total phosphorus, suspended solids and - on a discretionary basis - chlorides;

- minimum sampling frequency in sampling sites selected for load calculation is set at 24 per year;

- load calculation is processed according to the procedure recommended by the Project "Transboundary Assessment of Pollution Loads and Trends" (1998). Additionally, countries can calculate annual load by using their national calculation methods, results of which would be presented together with data prepared on the basis of the agreed method;

- countries should select for load assessment those TNMN monitoring sites where valid flow data is available (see Table 8.2.1).

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Table 8.2.1: List of TNMN stations selected for load assessment program.

Contry	River	Water quality monitoring station			Hydrological station	
		Contry Code	Location	Distance from the mouth (km)	Location	Distance from the mouth (km)
Germany	Danube	D02	Jochenstein	2204	Achleiten	2223
Germany	Inn	D03	Kirchdorf	195	Oberaudorf	211
Germany	Inn/Salzach	D04	Laufen	47	Laufen	47
Austria	Danube	A01	Jochenstein	2204	Aschach	2163
Austria	Danube	A04	Wolfsthal	1874	Hainburg (Danube)	1884
					Angern (March)	32
Czech Republic	Morava	CZ01	Lanzhot	79	Lanzhot	79
Czech Republic	Morava/Dyje	CZ02	Pohansko	17	Breclav-Ladná	32,3
Slovakia	Danube	SK01	Bratislava	1869	Bratislava	1869
Hungary	Danube	H03	Szob	1708	Nagymaros	1695
Hungary	Danube	H05	Hercegszántó	1435	Mohács	1447
Hungary	Tisza	H08	Tiszasziget	163	Szeged	174
Croatia	Danube	HR02	Borovo	1337	Borovo	1337
Croatia	Sava	HR06	Jesenice	729	Jesenice	729
Croatia	Sava	HR07	Una Jesenovac	525	Una Jesenovac	525
Croatia	Sava	HR08	Zupanja	254	Zupanja	254
Slovenia	Drava	SI01	Ormoz	300	Borl	325
					HE Formin	311
					Pesnica-Zamusani	10.1 (to the Drava)
Slovenia	Sava	SI02	Jesenice	729	Catez	737
					Sotla -Rakovec	8.1 (to the Sotla)
Romania	Danube	RO 02	Pristol-Novo Selo	834	Gruia	858
Romania	Danube	RO 04	Chiciu-Silistra	375	Chiciu	379
Romania	Danube	RO 05	Reni-Chilia arm	132	Isaccea	101
Ukraine	Danube	UA02	Vilkova-Kilia arm	18		

8.3 Monitoring Data 2001

In the second year of the load assessment programme, the agreed requirements on the programme have still not been fully met. Although slight improvements have been observed in the frequency of measurements, several monitoring stations still have lower measurement frequency than the required minimum. Data on dissolved phosphorus are available only for seven monitoring stations, located in Germany, Austria, Slovakia and Slovenia. Thus load of dissolved phosphorus was calculated there and is included in the Tables with results, but is not presented in the charts showing load in the context of the whole river basin.

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Table 8.3.1: Number of measurements in TNMN stations selected for assessment of pollution load in 2001.

Contry Code	River	Location	River Km	Number of							
				Q	SS	N_{inorg}	$P\text{-}PO_4$	P_{total}	BOD_5	CI	P_{diss}
DO2	Danube	Jochenstein	2204	365	26	26	26	26	26	26	27
D03	Inn	Kirchdorf	195	357	25	24	24	24	24	25	0
D04	Inn/Salzach	Laufen	47	360	26	26	26	26	26	26	26
A01	Danube	Jochenstein	2204	365	12	12	12	12	12	12	12
A04	Danube	Wolfsthal	1874	365	25	25	25	25	25	25	25
CZ01	Morava	Lanzhot	79	365	12	12	12	12	12	12	0
CZ02	Morava/Dyje	Pohansko	17	365	12	12	12	12	12	12	02
SK01	Danube	Bratislava	1869	365	25	25	25	25	24	25	12
H03	Danube	Szob	1708	365	26	26	26	26	26	26	0
H05	Danube	Hercegszanto	1435	365	23	36	36	36	36	23	0
H08	Tisza	Tiszasziget	163	365	13	26	26	26	26	13	0
HR02	Danube	Borovo	1337	0	26	26	26	26	26	0	0
HR06	Sava	Jesenice/D	729	365	26	26	26	26	26	12	0
HR07	Sava	us Una Jesenovac	525	365	26	26	26	26	26	12	0
HR08	Sava	ds Zupanja	254	365	26	26	26	26	26	12	0
SI01	Drava	Ormoz	300	365	24	24	24	0	24	24	24
SI02	Sava	Jesenice	729	365	24	24	24	0	24	24	24
RO02	Danube	Pristol-Novo Selo	834	365	19	21	21	15	20	21	0
RO04	Danube	Chiciu-Silistra	375	365	23	23	23	21	20	23	0
RO05	Danube	Reni-Chilia arm	132	365	23	23	23	21	23	23	0
UA02	Danube	Vilkov-Kilia arm	18	0	0	0	0	0	0	0	0

The frequency of measurements is crucial for assessment of pollution loads, and Table 8.3.1 shows the number of available data of discharge and selected determinands in 2001. Data from stations Danube-Jochenstein and Sava-Jesenice are included in the list by two neighbouring countries. Those from Danube-Jochenstein were combined in the process of load calculation, but calculation of load in location Sava-Jesenice was done separately from the data measured by Slovenia and Croatia. The reason for this is significant differences in the case of some determinands due to the use of differing methods of measurement. The harmonisation of the methods at bilateral level is in process.

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8.4 Calculation Procedure

The loads have been calculated in accordance with the following procedure:

- In the case of several sampling sites in the profile, average concentration at the station is calculated for each sampling day;

- In the case of values "below limit of detection", value of limit of detection is used in the further calculation;

- The average monthly concentrations are calculated according to the formula:

$$Cm\ [mg.l^{-1}] = \frac{\sum_{i \in m} C_i\ [mg.l^{-1}] \cdot Qi\ [m^3.s^{-1}]}{\sum_{i \in m} Qi\ [m^3.s^{-1}]}$$

where
C_m average monthly concentrations
C_i concentrations on the sampling days of each month
Q_i discharges on the sampling days of each month;

- The monthly load is calculated by using the formula:

$$L\ m\ [tones] = C_m\ [mg.l^{-1}] \cdot Qm\ [m^3.s^{-1}] \cdot days\ (m) \cdot 0{,}0864$$

where
L_m monthly load
Q_m average monthly discharge

- If discharges are available only for the sampling days, Qm is calculated from those discharges.

- In the case of months without measured values the average of the products Cm.Qm in the months with sampling days is used;

- The annual load is calculated as the sum of the monthly loads:

$$La\ [tones] = \sum_{m=1}^{12} L_m\ [tones]$$

8.5 Results

The mean annual concentrations and annual loads of suspended solids, inorganic nitrogen, ortho-phosphate-phosphorus, total phosphorus, BOD5, chlorides and – where available – dissolved phosphorus are presented in Tables 8.5.1 to 8.5.4, separately for monitoring stations located on the Danube River and monitoring stations located on tributaries. Explanation of terms used in Tables 8.5.1 - 8.5.4 is to be found in the following legend.

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Term used	Explanation
Station Code	TNMN monitoring station code
Profile	location of sampling site in profile (L-left, M-middle, R-right)
River Name	name of river
Location	name of monitoring site
River km	distance to mouth of the river
Q_a	mean annual discharge in the year 2001
c_{mean}	arithmetical mean of the concentrations in the year 2001
Annual Load	annual load of given determinand in the year 2001

The mean annual discharge and annual loads of suspended solids, inorganic N, ortho-phosphate P, total P, BOD5 and chlorides are presented on the plots, prepared separately for monitoring stations located on the Danube River and stations located on its primary tributaries (Figures 8.5.1 – 8.5.12). Looking at the Figures with calculated values of annual load, it is necessary to restate that in accordance with results of QualcoDanube proficiency testing comparability of BOD data analysed by laboratories included in the TNMN network is still not satisfactory.

Figures 8.5.1 – 8.5.12 show that the spatial pattern of annual load along the Danube River is similar to the previous year. In the Danube River itself, load of organic pollution and nutrients generally increases from the upper to the lower part of the river. An annual load of suspended solids decreases in the middle part of the Danube River due to reduced flow velocity through damming, and reaches its maximum at the beginning of the lower Danube River section (at monitoring station RO02). Similarly, the highest annual load values of BOD_5, ortho-phosphate-P and total P are observed there.

In the case of tributaries, as in year 2001 discharge data have been available from the most downstream station on Sava River (HR08 – Sava-ds. Zupanja), and in the Figures load from this location is shown instead of Sava-Jesenice. Therefore while in the previous year the Tisza River showed the highest load among the tributaries, in 2001 the highest load of inorganic N, total P and BOD_5 is observed in Sava River. Regarding ortho-phosphate phosphorus and suspended solids, the highest contribution to the load of the Danube comes from the Tisza River.

Table 8.5.1: Mean annual concentrations in monitoring stations selected for load assessment on Danube River.

Station Code	Profile	River Name	Location	River Km	Q_a	c_{mean}						
						Suspended Solids	Inorganic Nitrogen	Ortho-Phosphate Phosphorus	Total Phos-phorus	BOD_5	Chlorides	Phosphorus dissolved
					($m^3.s^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)
D02+A01	M	Danube	Jochenstein	2204	1627.6	53	2.25	0.032	0.09	2.0	15	0.036
A04	R	Danube	Wolfsthal	1874	2218.2	25	2.20	0.029	0.07	1.3	16	0.039
SK01	M	Danube	Bratislava	1869	2231.3	27	2.32	0.042	0.10	2.0	17	0.066
H03	LMR	Danube	Szob	1708	2382.3	22	2.00	0.063	0.13	4.4	22	
H05	M	Danube	Hercegszántó	1435	2432.5	24	2.07	0.053	0.15	3.5	18	
RO02	LMR	Danube	Pristol-Novo Selo	834	5421.8	45	1.61	0.100	0.11	3.4	20	
RO04	LMR	Danube	Chiciu-Silistra	375	5919.4	15	2.35	0.029	0.05	1.9	31	
RO05	LMR	Danube	Reni-Chilia arm	132	6304.3	19	2.22	0.028	0.06	1.5	32	

Table 8.5.2: Mean annual concentrations in monitoring stations selected for load assessment on tributaries.

Station Code	Profile	River Name	Location	River Km	Q_a	c_{mean}						
						Suspended Solids	Inorganic Nitrogen	Ortho-Phosphate Phosphorus	Total Phos-phorus	BOD_5	Chlorides	Phosphorus dissolved
					($m^3.s^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)	($mg.l^{-1}$)
D03	M	Inn	Kirchdorf	195	320.3	57	0.57	0.011	0.09	1.1	4	
D04	L	Inn/Salzach	Laufen	47	252.6	28	0.72	0.018	0.06	2.2	7	0.022
CZ01	M	Morava	Lanzhot	79	67.2	22	3.17	0.131	0.22	3.7	25	
CZ02	L	Morava/Dyje	Pohansko	17	32.1	17	3.55	0.218	0.27	3.9	44	
H08	LMR	Tisza	Tiszasziget	163	921.4	113	1.21	0.063	0.23	1.8	31	
SI01	L	Drava	Ormoz	300	294.4	11	1.02	0.012		2.2	4	0.023
SI02	R	Sava	Jesenice	729	276.8	31	1.44	0.056		2.8	6	0.074
HR06	L	Sava	Jesenice	729	188.2	13	1.60	0.026	0.17	2.2	7	
HR07	L	Sava	us. Una Jasenovac	525	585.0	12	1.01	0.040	0.23	2.5	8	
HR08	R	Sava	ds. Zupanja	254	1102.4	38	1.68	0.016	0.22	2.5	15	

Table 8.5.3: Annual load in selected monitoring stations on Danube River.

Station Code	Profile	River Name	Location	River Km	Annual Load						
					Suspended Solids	Inorganic Nitrogen	Ortho-Phosphate Phosphorus	Total Phos-phorus	BOD_5	Chlorides	Phosphorus dissolved
D02					($x10^6$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^6$tonns)	($x10^3$tonns)
+A01	M	Danube	Jochenstein	2204	4.1	116	1.6	5.9	106	0.7	1.8
A04	R	Danube	Wolfsthal	1874	1.9	152	2.0	5.2	89	1.1	2.7
SK01	M	Danube	Bratislava	1869	2.3	159	3.0	7.3	145	1.1	4.4
H03	LMR	Danube	Szob	1708	1.7	149	4.7	9.6	336	1.6	
H05	M	Danube	Hercegszántó	1435	2.0	157	4.0	12.1	268	1.4	
RO02	LMR	Danube	Pristol-Novo Selo	834	8.0	286	16.9	18.4	584	3.4	
RO04	LMR	Danube	Chiciu-Silistra	375	2.7	429	5.3	9.9	378	5.7	
RO05	LMR	Danube	Reni-Chilia arm	132	3.7	437	5.2	13.1	303	6.3	

Table 8.5.4: Annual load in selected monitoring stations on tributaries.

Station Code	Profile	River Name	Location	River Km	Annual Load						
					Suspended Solids	Inorganic Nitrogen	Ortho-Phosphate Phosphorus	Total Phos-phorus	BOD_5	Chlorides	Phosphorus dissolved
					($x10^6$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^3$tonns)	($x10^6$tonns)	($x10^3$tonns)
D03	M	Inn	Kirchdorf	195	1.17	5.1	0.10	1.62	11.0	0.03	
D04	L	Inn/Salzach	Laufen	47	0.37	5.3	0.13	0.64	17.1	0.05	0.16
CZ01	M	Morava	Lanzhot	79	0.05	6.7	0.27	0.49	7.7	0.05	
CZ02	L	Morava/Dyje	Pohansko	17	0.02	4.0	0.19	0.27	4.2	0.04	
H08	LMR	Tisza	Tiszasziget	163	3.59	35.4	1.60	6.47	48.8	0.83	
SI01	L	Drava	Ormoz	300	0.12	9.1	0.12		19.6	0.04	0.22
SI02	R	Sava	Jesenice	729	0.53	11.8	0.38		25.2	0.04	0.52
HR06	L	Sava	Jesenice	729	0.14	8.2	0.15	0.94	11.4	0.02	
HR07	L	Sava	us. Una Jasenovac	525	0.21	18.8	0.63	3.87	40.7	0.13	
HR08	R	Sava	ds. Zupanja	254	1.63	60.4	0.61	7.65	90.9	0.42	

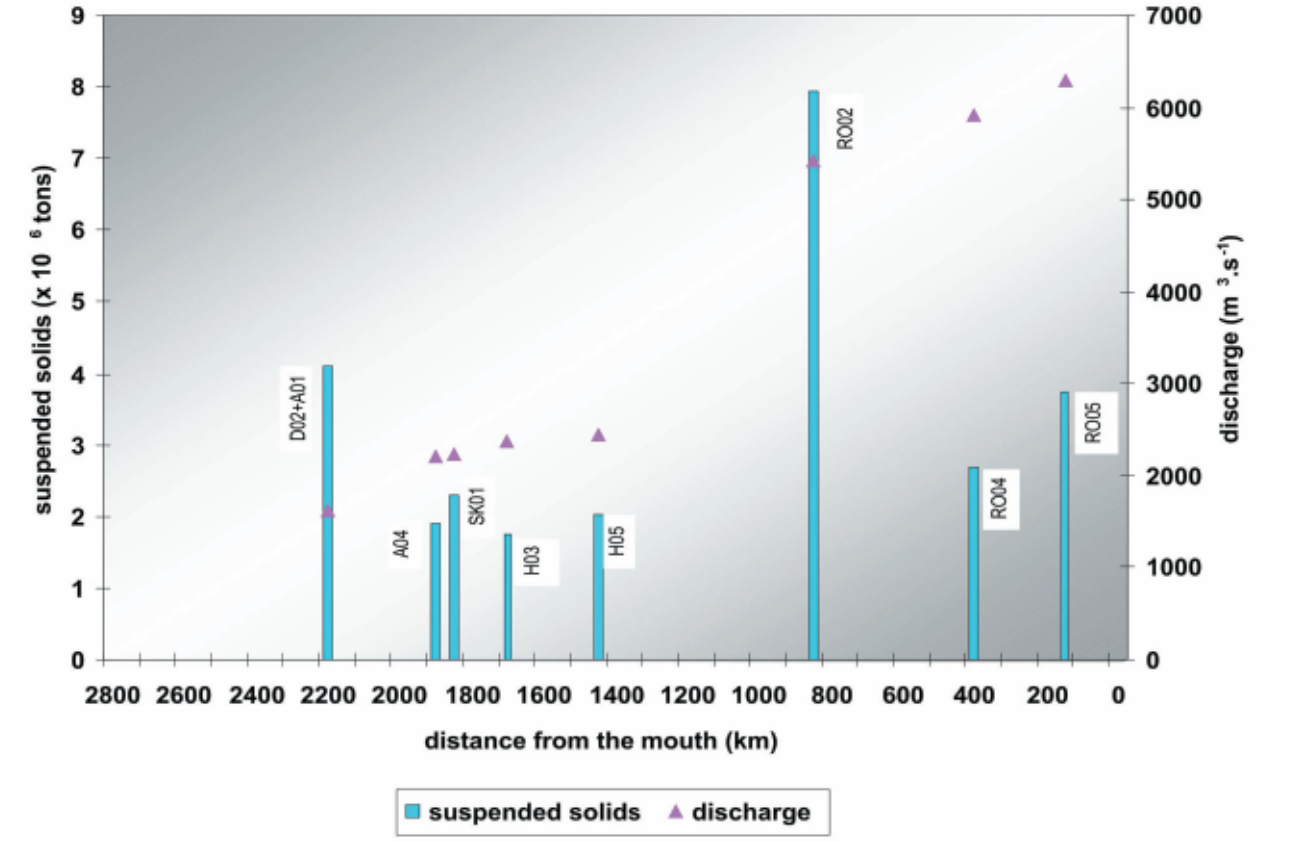

Figure 8.5.1: Annual load of suspended solids at monitoring stations along the Danube River.

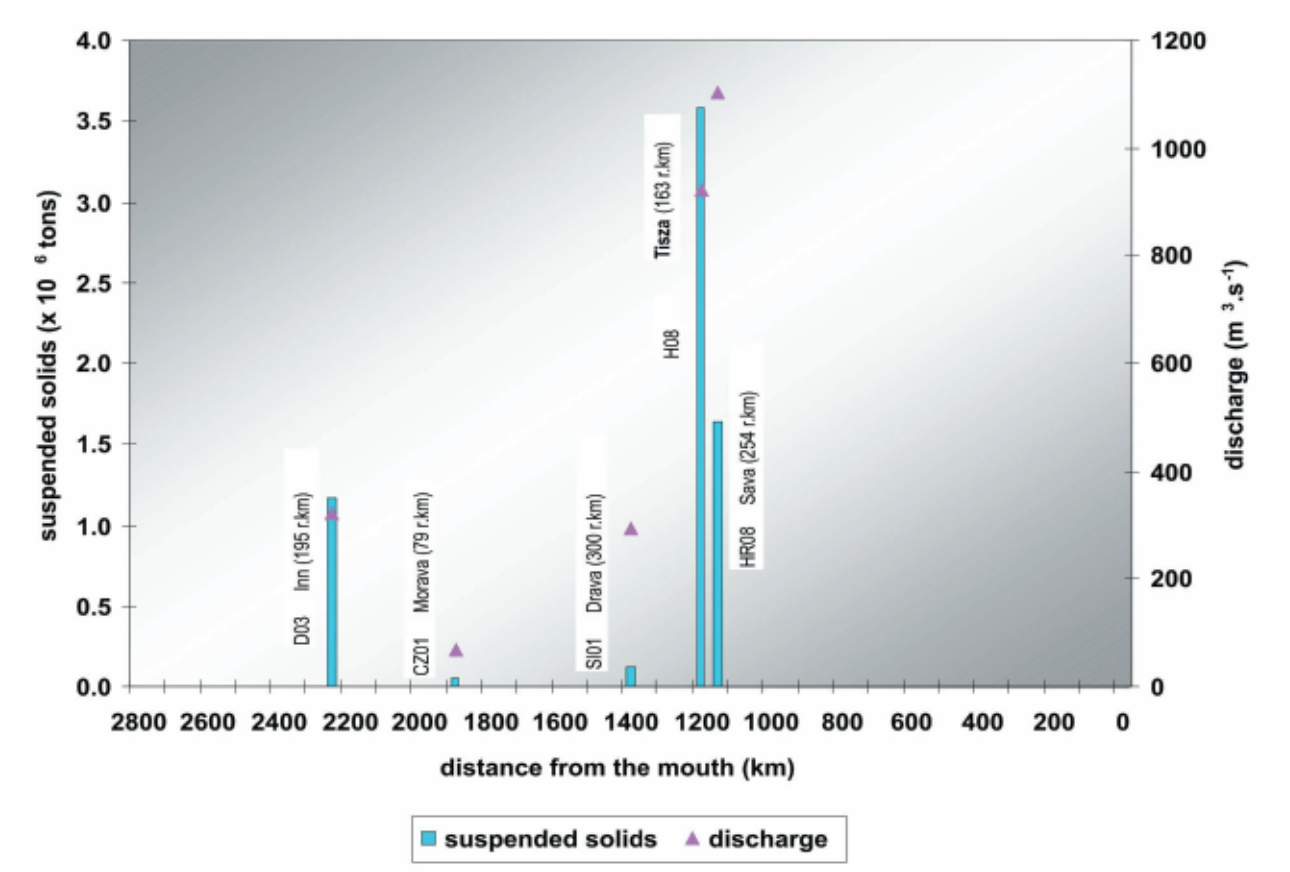

Figure 8.5.2: Annual load of suspended solids at monitoring stations on tributaries.

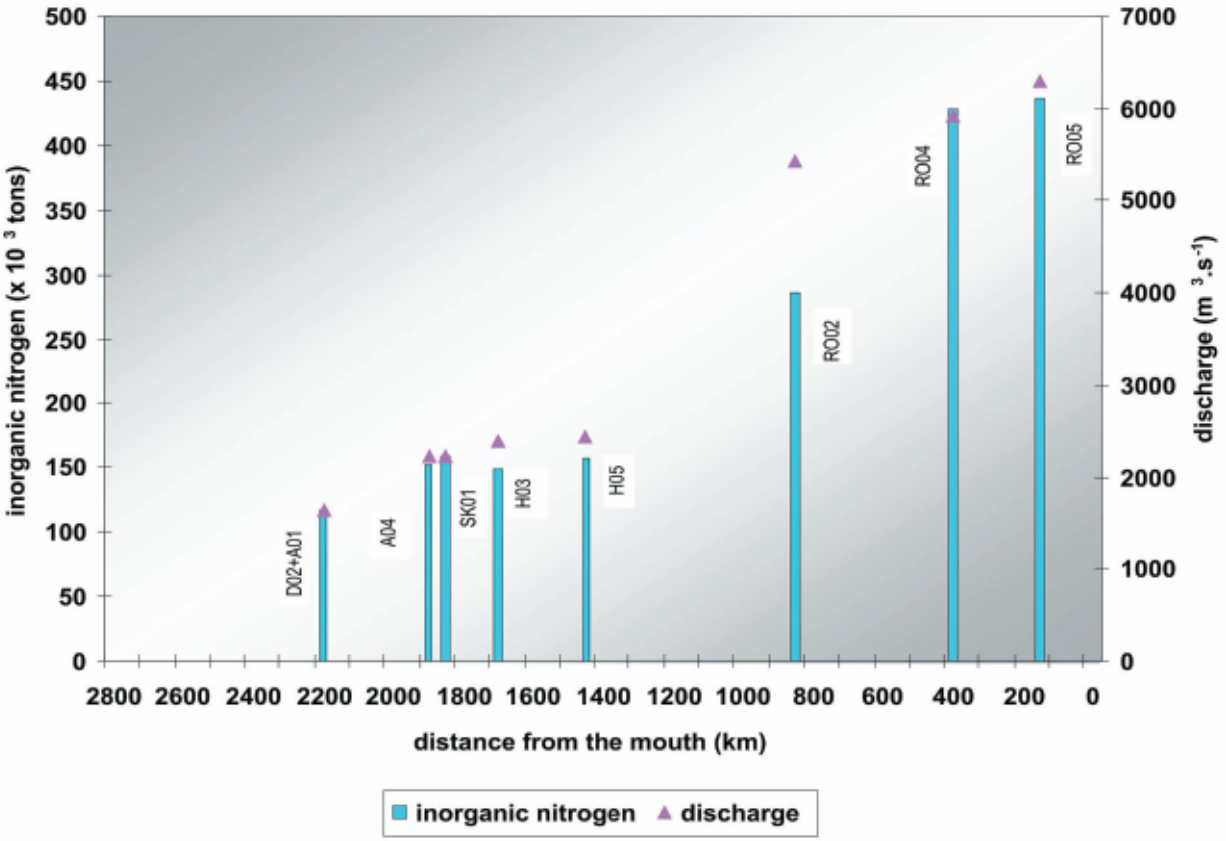

Figure 8.5.3: Annual load of inorganic nitrogen at monitoring stations along the Danube River.

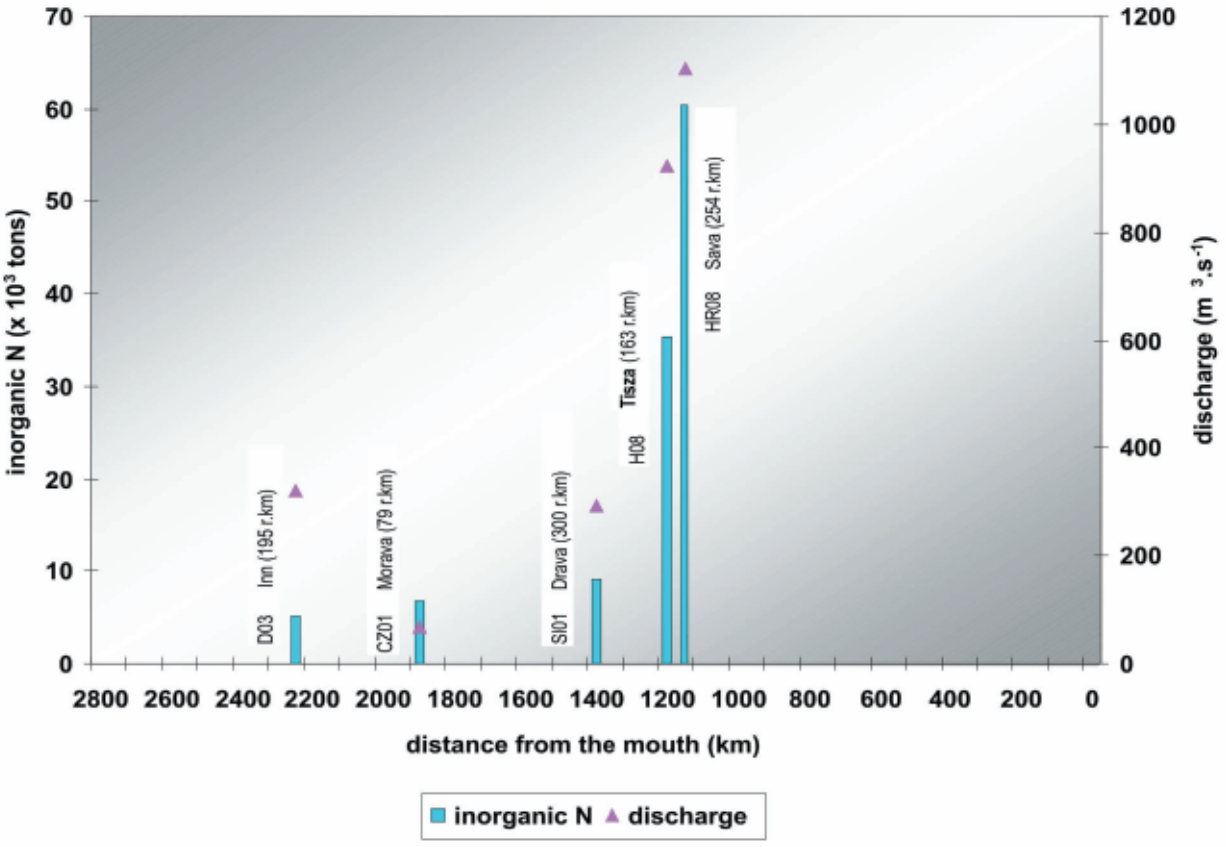

Figure 8.5.4: Annual load of inorganic nitrogen at monitoring stations on tributaries.

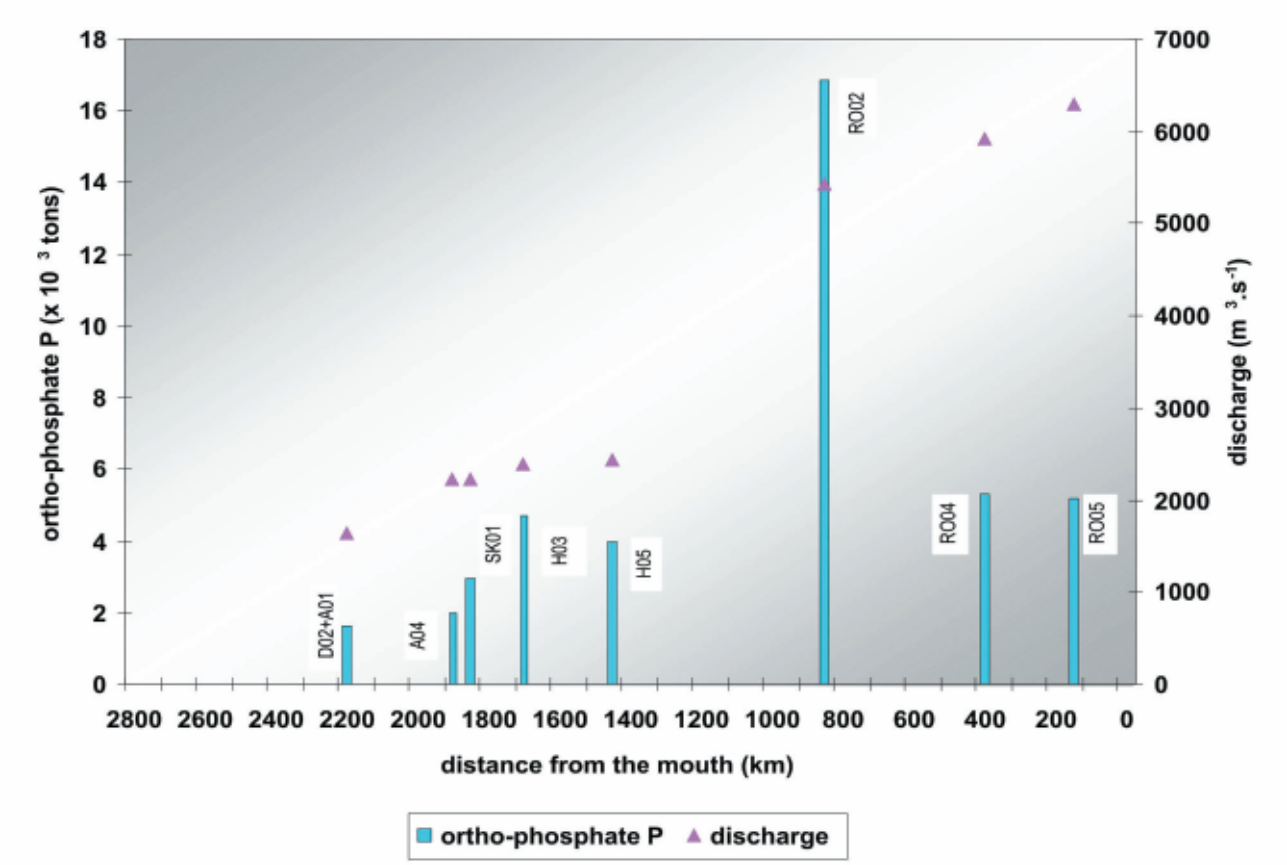

Figure 8.5.5: Annual load of ortho-phosphate-P at monitoring stations along the Danube River.

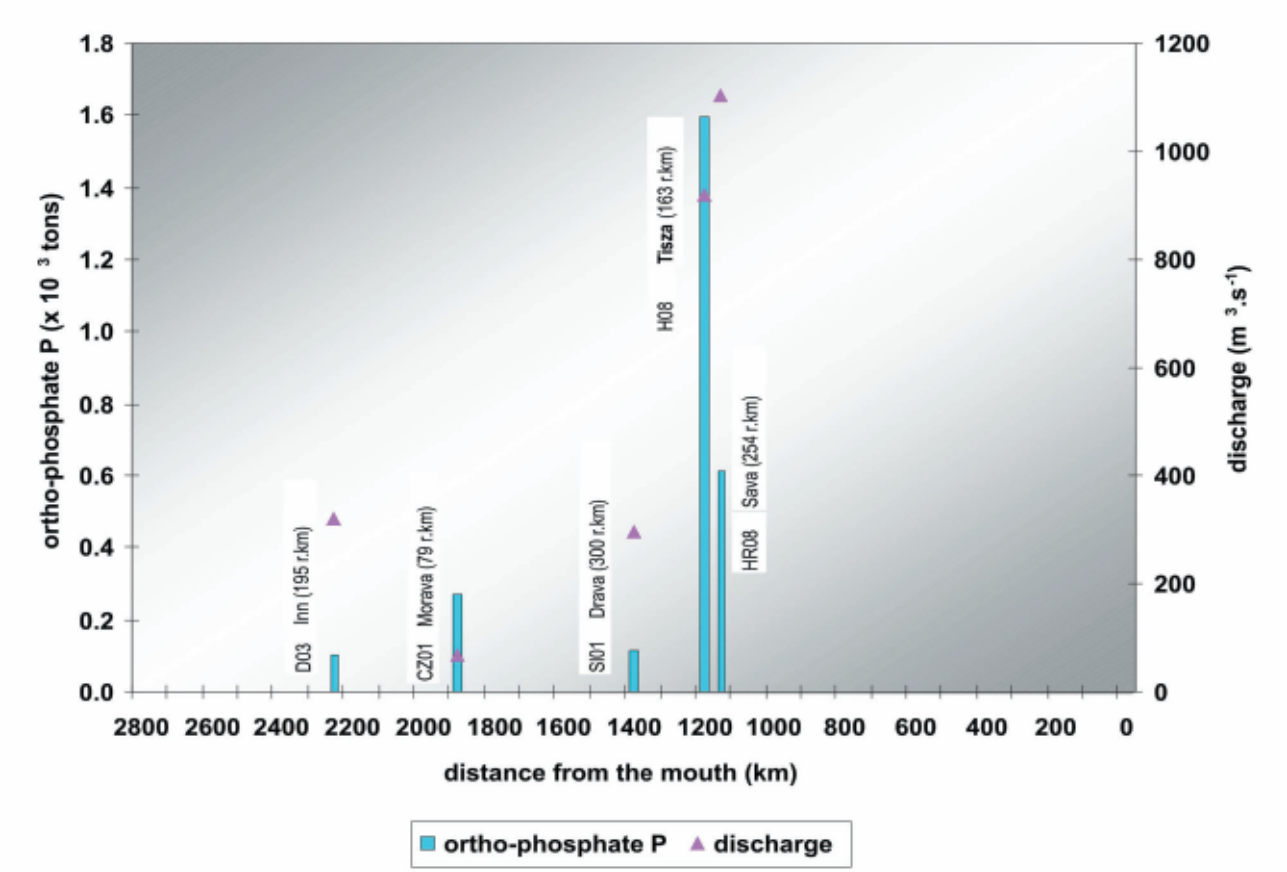

Figure 8.5.6: Annual load of ortho-phosphate-P at monitoring stations on tributaries.

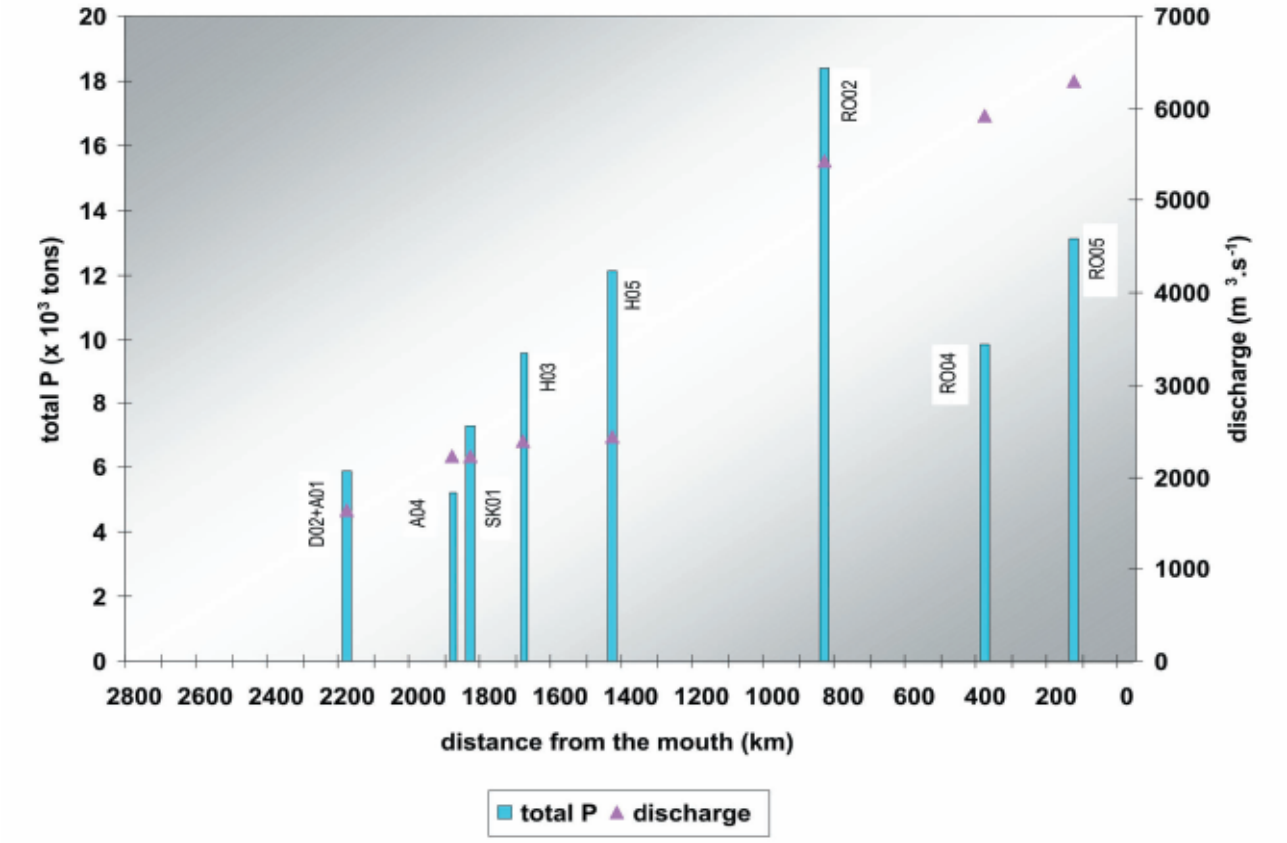

Figure 8.5.7: Annual load of total phosphorus at monitoring stations along the Danube River.

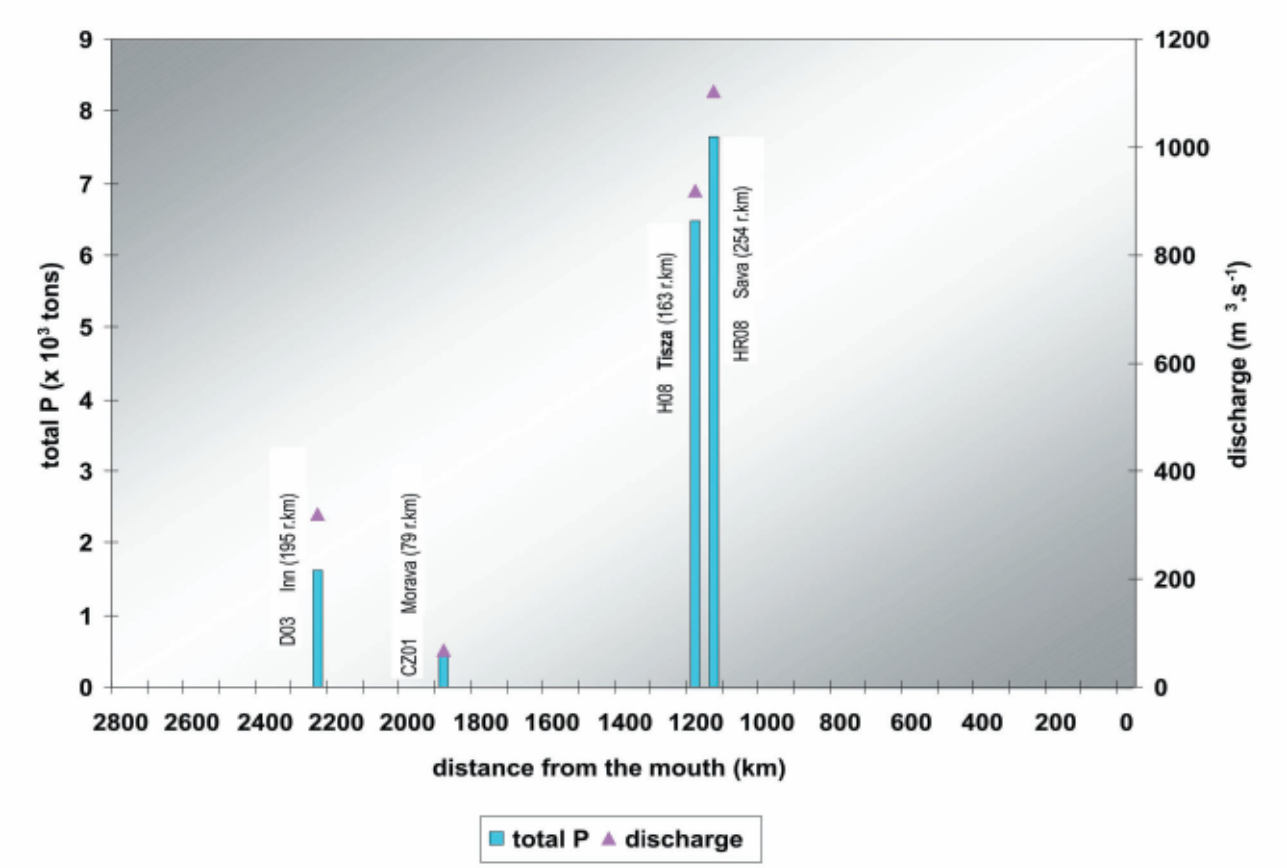

Figure 8.5.8: Annual load of total phosphorus at monitoring stations on tributaries.

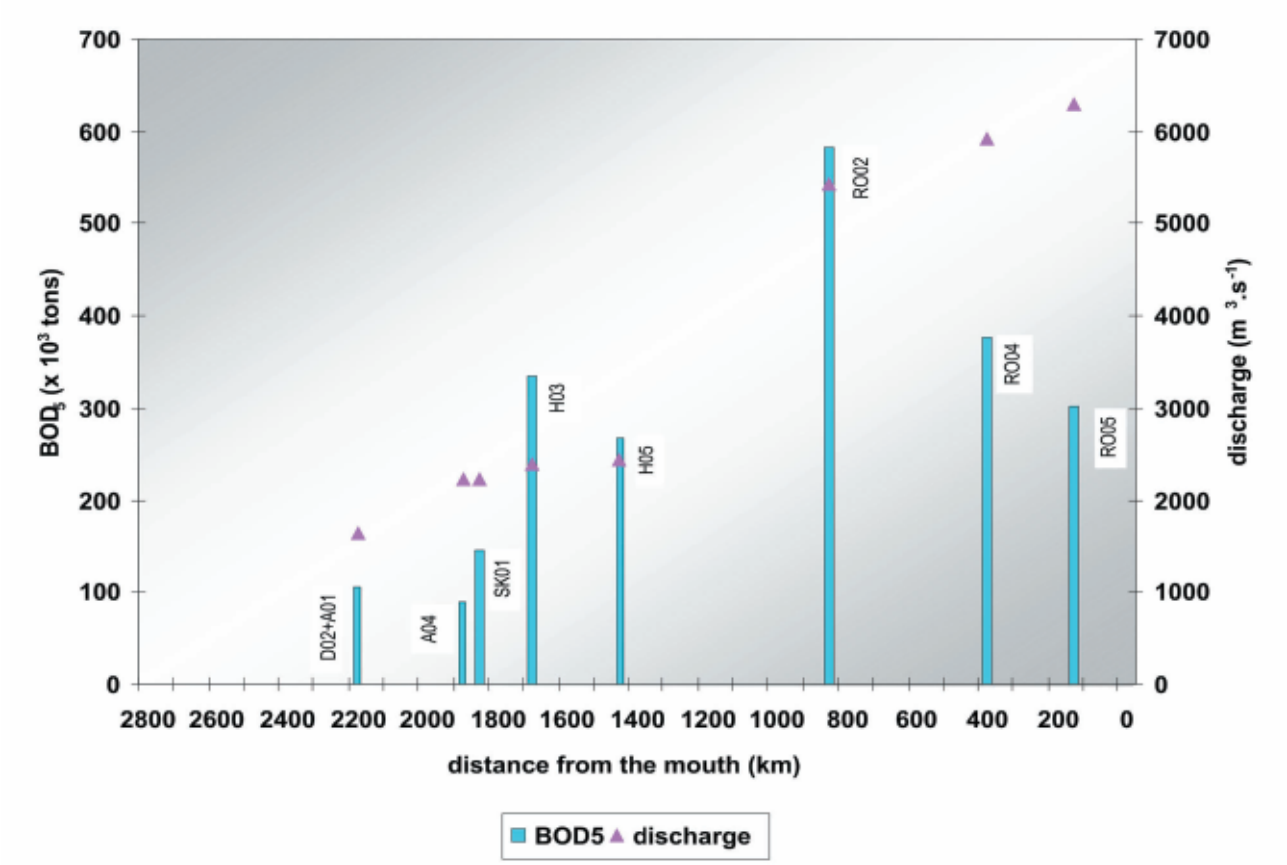

Figure 8.5.9: Annual load of BOD_5 at monitoring stations along the Danube River.

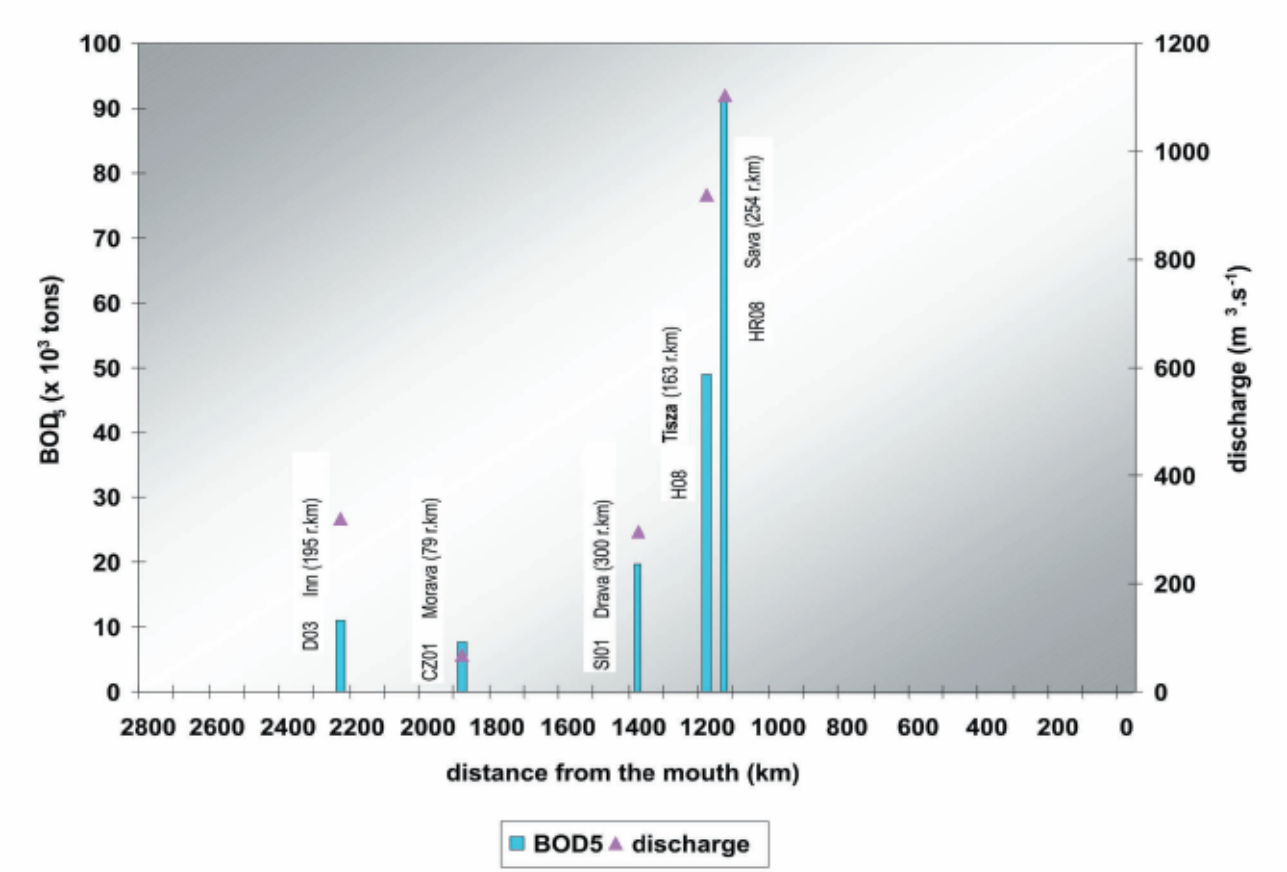

Figure 8.5.10: Annual load of BOD_5 at monitoring stations on tributaries.

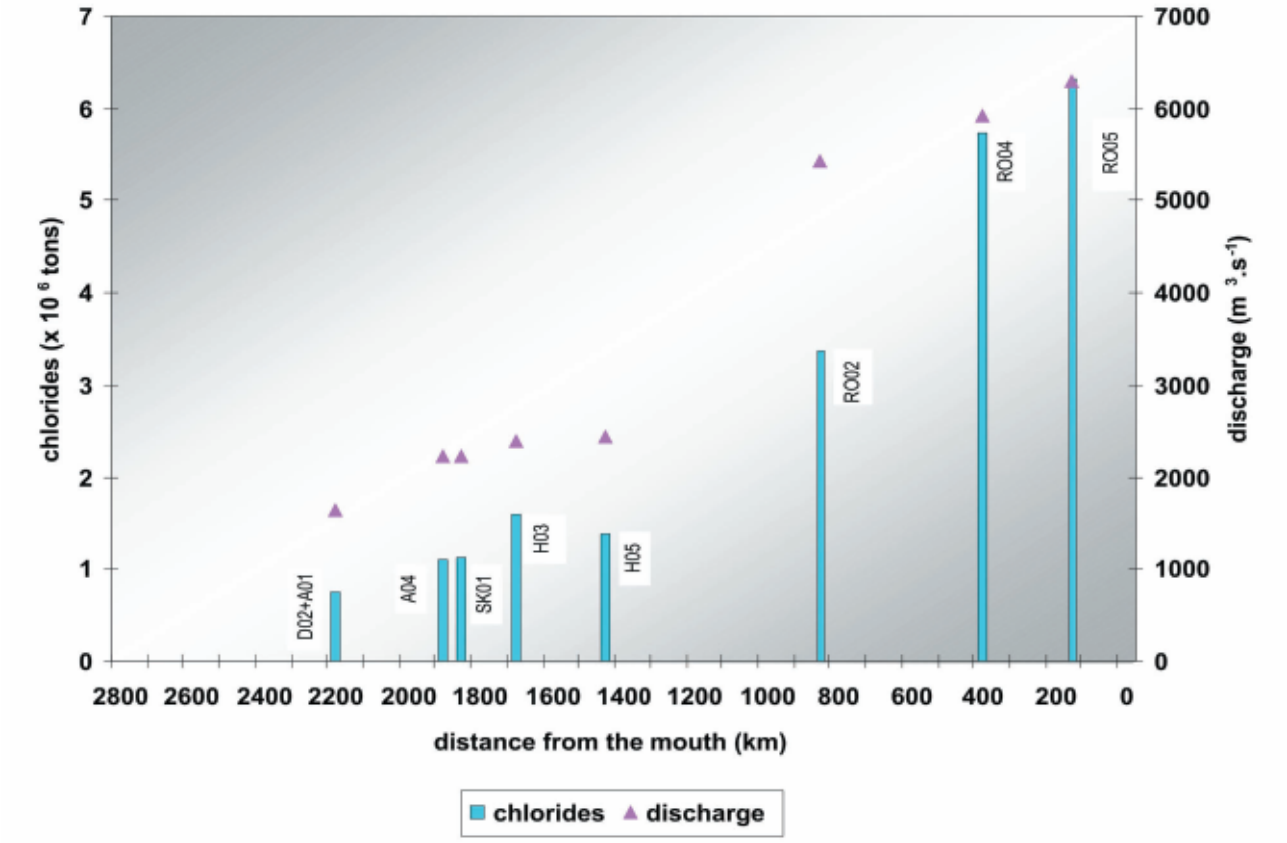

Figure 8.5.11: Annual load of chlorides at monitoring stations along the Danube River.

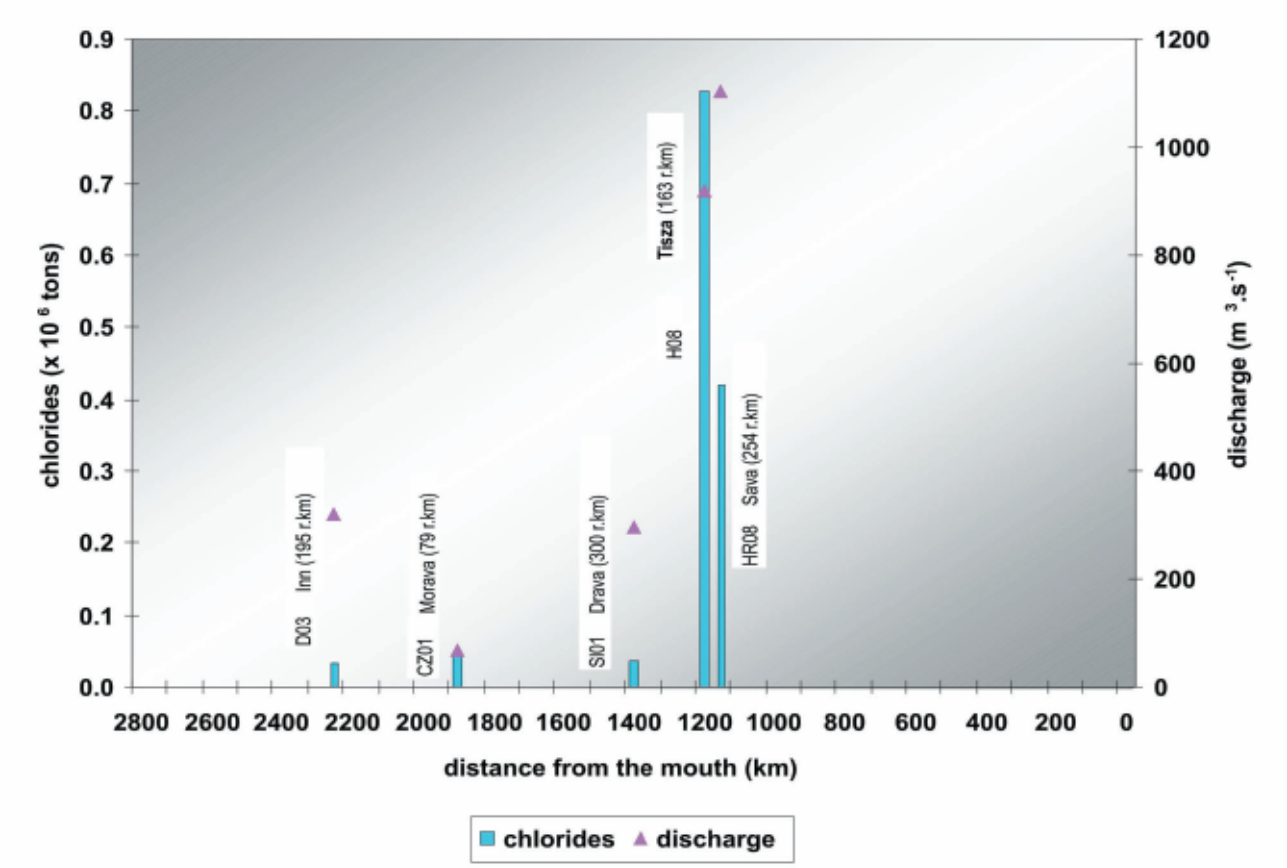

Figure 8.5.12: Annual load of chlorides at monitoring stations on tributaries.