INFLUENCE OF THE BULGARIAN TRIBUTARIES ON THE DANUBE HYDROCHEMICAL LOADS

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Abstract: The present material has a goal to reveal the contemporary condition of the water quality at the estuary parts of the major Bulgarian tributaries and their impact on the Danube river water quality through the hydrochemical loads. The Bulgarian Danube tributaries are not big ones and they are located in the lowest part of the Danube river where is expected the hydrochemical content is mainly formed up-stream. Nevertheless the Bulgarian tributaries have some influence that should not be neglected and could be assessed. The presented values show that the influence of the different water quality loads in Bulgarian rivers is different but the total hydrochemical loads contribution annually does not increase several percents.
Keywords: the Danube, water quality, hydrochemical loads

EINFLUSS DER BULGARISCHEN NEBENFLUESSE AUF DIE HYDROCHEMISCHE BELASTUNG DES DONAUFLUSSES

Zusammenfassung: Die hydrochemischen Stoffbelastungen für die bulgarischen Nebenflüssen vom Fluss Donau sind bestimmt für die folgenden Parameter: Parameter des Sauerstoffregimes und des organischen Inhalts - gelöster Sauerstoff (O_2), biochemisches Bedürfnis vom Sauerstoff (BOD5), Permanganatoxydation (Ox); biogenische Komponenten – Nitratstickstoff ($N\text{-}NO_3$), Nitritstiskstoff ($N\text{-}NO_2$), Ammoniumstickstoff ($N\text{-}NH_4$), Phosphaten (PO_4); Mineralinhaft – Summe Ionen (SUM); Inhalt von ungelösten Stoffen (Sus). Die hydrochemischen Stoffbelastungen in 9 Monitoringstationen, gelegen an der Mündungen der wichtigsten bulgarischen Nebenflüssen, sind geschätzt.
Schlüsselworte: Donau, Wasserqualität, hydrochemische Stoffbelastungen

The influence of the national tributaries on the Danube mainstream water quality is always important and some times contradictory issue. The present material has a goal to reveal the contemporary condition of the water quality at the estuary parts of the major Bulgarian tributaries and their impact on the Danube river water quality through the hydrochemical loads. The investigation has a pretension to deal with the newer water quality data reflecting the occurred events in the Bulgarian economy after the changes in the last decade. For this goal are collected hydrological and hydrochemical data for the period 1996-2000 at the estuary parts of all main Bulgarian tributaries at their last monitoring stations as follow: Voinishka river – at the Tarniane village, Lom river – at the Lom town, Tzibritza river – at the Dolni Tzibar village, Ogosta river – at the Mizia town, Iskar river – at the Oriachovitza village, Vit river – at the Guliantzi village, Ossam river – at the Izgrev village, Jantra river – at the Novgrad village, Russenski Lom river – at the Basarbovo village.

The hydrochemical loads in the Bulgarian Danube tributaries are established using nine water quality parameters grouped as: parameters of oxygen regime and organic content - dissolved oxygen (O_2), biochemical oxygen demand (BOD5), permanganate oxidation (Ox); biogenic components – nitrate nitrogen ($N\text{-}NO_3$), nitrite nitrogen ($N\text{-}NO_2$), ammonium nitrogen ($N\text{-}NH_4$), phosphate (PO_4); mineral content – dissolved materials (DM); content of suspended matters (Sus). The mentioned above main water quality parameters assess well water quality conditions according to the Bulgarian standards (Ordinance 7, 1986) and represent the major part of the transported pollutants in the river streams.

The estimation of hydrological loads transported by the rivers depends on accuracy and frequency of water quality sampling. There is a difference in the frequency of sampling but no more then monthly gauges for each station. Furthermore the information is incomplete at some stations**.** Because of the non-homogeneity of the water quality information the direct determining of average values is not correct. This is the reason to use a methodology based on the relationship between the studied water quality parameters and the water discharge (Tzankov, 1998).

The accumulated Bulgarian experience (Tzankov, 1998) shows that some statistical relationship is significant if the obtained coefficient of correlation has a value no less r^2>=0.25 when the number of the studied parameters in the row is more then 20-30.

From these relationships using the average monthly water discharges (Qmonthly) the average monthly water quality concentrations (Cmonthly) can be determined.

The annual loads for different parameters (C_i) characterizing the water quality for the chosen period is used the formula:

L_i annual load = Σ [C_{ij} average, monthly x Q_{ij} average, monthly] (t/year),

Where:

L_i annual load – annual load for some parameter, characterizing water quality (t/year),

C_{ij} average, monthly - concentration of the water quality parameter, given by the regression analyses, according to the average monthly water discharge (mg/l),

Q_{ij} average, monthly - average monthly water discharge (m^3/s)

i - number of the year; j – number of the month.

The average loads for the studied period are calculated from the annual loads. The results for annual loads, total loads for the studied periods and average annual loads are shown on the Table 1.

Table 1 Annual loads, total loads and average annual loads for 1996-2000 in t/year

period	O_2	BOD5	Ox	N-NO_3	N-NO_2	N-NH_4	PO_4	DM	Sus
	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year
Voinishka river (inflow into the Danube at km 782.2)									
1996	167.4	40.2	65.5	8.9	0.2	4.1	1.3	7429.8	1111.4
1997	306.2	63.0	97.9	12.2	0.4	5.6	2.1	11105.9	3085.5
1998	332.6	65.9	102.4	12.3	0.4	5.7	2.2	11585.1	3535.4
1999	249.5	49.4	76.8	9.2	0.3	4.3	1.7	8688.8	2651.5
2000	292.7	58.0	90.1	10.8	0.3	5.0	2.0	10194.9	3111.1
Total (t)	**1348.4**	**276.4**	**432.8**	**53.4**	**1.6**	**24.7**	**9.2**	**49004.6**	**13495.0**
Average (t)	**269.7**	**55.3**	**86.6**	**10.7**	**0.3**	**4.9**	**1.8**	**9800.9**	**2699.0**
Lom river (inflow into the Danube at km 741.6)									
1996	2494.3	483.1	686.7	63.3	1.9	17.7	11.3	48367.0	8672.7
1997	2060.3	419.6	592.5	51.7	1.6	14.5	9.8	41879.1	7180.6
1998	1759.0	392.3	560.9	44.1	1.6	12.4	11.2	39620.6	6152.4
1999	1319.3	294.2	420.7	33.1	1.2	9.3	8.4	29715.5	4614.3
2000	1548.0	345.2	493.6	38.8	1.4	10.9	9.9	34866.1	5414.1
Total (t)	**9180.9**	**1934.3**	**2754.3**	**231.0**	**7.6**	**64.9**	**50.6**	**194448.3**	**32034.1**
Average (t)	**1836.2**	**386.9**	**550.9**	**46.2**	**1.5**	**13.0**	**10.1**	**38889.7**	**6406.8**

period	O_2	BOD5	Ox	$N\text{-}NO_3$	$N\text{-}NO_2$	$N\text{-}NH_4$	PO_4	DM	Sus
	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year
Tzibritza river (inflow into the Danube at km 715.9)									
1996	475.2	132.1	205.7	40.3	2.2	7.4	9.3	22673.4	3030.9
1997	233.9	83.6	128.6	24.3	1.5	4.8	7.3	14385.6	1555.8
1998	396.4	114.9	172.4	35.1	1.9	6.8	8.1	19135.4	2601.2
1999	297.3	86.2	129.3	26.3	1.4	5.1	6.1	14351.5	1950.9
2000	348.8	101.1	151.7	30.9	1.6	6.0	7.1	16839.1	2289.0
Total (t)	**1751.5**	**517.8**	**787.7**	**156.7**	**8.6**	**30.1**	**37.8**	**87384.9**	**11427.8**
Average (t)	**350.3**	**103.6**	**157.5**	**31.3**	**1.7**	**6.0**	**7.6**	**17477.0**	**2285.6**
Ogosta river (inflow into the Danube at km 684.7)									
1996	4219.8	1374.9	1477.0	598.0	7.5	156.0	242.1	143921.6	24152.2
1997	4952.2	1514.8	1706.9	685.3	8.2	156.3	279.3	164757.7	28301.3
1998	5295.7	1615.4	1724.8	646.0	8.7	168.4	272.6	170333.0	34231.2
1999	3971.8	1211.5	1293.6	484.5	6.5	126.3	204.4	127749.8	25673.4
2000	4660.2	1421.6	1517.9	568.5	7.7	148.2	239.9	149893.0	30123.5
Total (t)	**23099.7**	**7138.2**	**7720.2**	**2982.4**	**38.6**	**755.3**	**1238.2**	**756655.2**	**142481.6**
Average (t)	**4619.9**	**1427.6**	**1544.0**	**596.5**	**7.7**	**151.1**	**247.6**	**151331.0**	**28496.3**
Iskar river (inflow into the Danube at km 636.4)									
1996	16931.7	5266.5	7472.1	854.2	48.2	308.2	536.9	460904.6	113760.8
1997	15570.8	5003.6	7505.7	851.7	43.7	308.6	507.9	444512.9	96616.0
1998	15610.5	4867.7	8146.6	910.7	44.7	328.1	509.5	464033.6	89448.3
1999	11707.8	3650.8	6109.9	683.0	33.5	246.1	382.1	348025.2	67086.3
2000	13737.2	4283.6	7169.0	801.4	39.3	288.7	448.3	408349.5	78714.5
Total (t)	**73558.1**	**23072.3**	**36403.3**	**4101.1**	**209.4**	**1479.7**	**2384.6**	**2125825.8**	**445625.9**
Average (t)	**14711.6**	**4614.5**	**7280.7**	**820.2**	**41.9**	**295.9**	**476.9**	**425165.2**	**89125.2**
Vit river (inflow into the Danube at km 609.4)									
1996	1996.0	1450.3	2230.3	245.9	19.1	231.0	123.0	144154.9	15940.37
1997	1997.0	1376.7	2126.7	233.9	18.3	223.4	117.8	137765.6	15124.15
1998	1998.0	1125.3	1723.2	188.2	16.4	181.9	101.9	116228.5	11097.56
1999	1498.5	844.0	1292.4	141.1	12.3	136.4	141.0	87171.4	8323.2
2000	1758.2	962.0	990.2	152.0	16.5	145.0	160.1	102281.1	6242.4
Total (t)	**9247.7**	**5758.2**	**8362.9**	**961.1**	**82.6**	**917.7**	**643.8**	**587601.6**	**56727.6**
Average (t)	**1849.5**	**1151.6**	**1672.6**	**192.2**	**16.5**	**183.5**	**128.8**	**117520.3**	**11345.5**
Ossam river (inflow into the Danube at km 599.9)									
1996	2909.1	1182.4	1320.7	228.4	10.4	117.9	33.3	116752.3	18032.7
1997	3292.0	1309.1	1473.7	257.3	11.6	127.8	36.6	131057.3	22097.9
1998	2951.4	1193.9	1356.9	230.9	10.8	118.8	34.3	119208.2	18010.6
1999	2213.6	895.4	1017.7	173.2	8.1	89.1	25.8	89406.2	13508.0
2000	2597.2	1050.6	1194.1	203.2	9.5	104.5	30.2	104903.2	15849.3
Total (t)	**13963.3**	**5631.5**	**6363.1**	**1092.9**	**50.3**	**558.1**	**160.2**	**561327.2**	**87498.5**
Average (t)	**2792.7**	**1126.3**	**1272.6**	**218.6**	**10.1**	**111.6**	**32.0**	**112265.4**	**17499.7**

period	O_2	BOD5	Ox	$N\text{-}NO_3$	$N\text{-}NO_2$	$N\text{-}NH_4$	PO_4	DM	Sus
	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year	t/year
Iantra river (inflow into the Danube at km 536.6)									
1996	12963.5	7714.7	8442.4	733.0	61.7	349.0	184.4	469464.9	59565.0
1997	12569.7	7495.0	8219.8	710.9	59.8	339.1	183.0	455279.4	64147.4
1998	13796.2	6123.8	8857.4	773.6	65.3	366.5	191.2	494124.1	77750.9
1999	10347.1	6092.9	6643.0	580.2	49.0	274.8	143.4	370593.1	58313.2
2000	12140.6	6148.9	7794.5	680.7	57.4	322.5	168.3	434829.2	68420.8
Total (t)	**61817.0**	**33575.2**	**39957.0**	**3478.5**	**293.3**	**1651.8**	**870.4**	**2224290.6**	**328197.4**
Average (t)	**12363.4**	**6715.0**	**7991.4**	**695.7**	**58.7**	**330.4**	**174.1**	**444858.1**	**65639.5**
Russenski Lom river (inflow into the Danube at km 497.9)									
1996	1422.3	1379.1	1536.4	347.0	5.1	117.0	101.2	106830.8	53679.9
1997	1596.3	1515.1	1714.1	390.6	5.6	134.4	78.7	119739.9	61660.1
1998	2138.3	1944.3	2291.9	527.2	7.3	199.0	69.4	156862.6	91399.4
1999	1603.7	1458.3	1719.0	395.4	5.5	149.2	52.0	117646.9	68549.5
2000	1881.7	1711.0	2016.9	463.9	6.4	175.1	61.0	138039.1	80431.4
Total (t)	**8642.4**	**8007.8**	**9278.3**	**2124.0**	**29.9**	**774.7**	**362.3**	**639119.4**	**355720.3**
Average (t)	**1728.5**	**1601.6**	**1855.7**	**424.8**	**6.0**	**154.9**	**72.5**	**127823.9**	**71144.1**
TOTAL	***40521.8***	***17182.4***	***22411.9***	***3036.2***	***144.4***	***1251.4***	***1151.4***	***1445131.5***	***294641.7***

The results reveal a contradictory tendency of alteration of hydrochemical loads in the range of the observed period. From the point of view of water pollution and wastewater discharges, as a main reason for water quality formation, the studied period is homogenous. For the periods with not big change of water quality characteristics the tendency of alteration of the hydrochemical loads in all rivers depend on the hydrological regime for each year. Obviously the presented variation of values for the estuary parts of the Bulgarian tributaries can be explained by the regime of water discharges during the period 1996-2000.

On Figures 1-6 the average annual hydrochemical loads in tons for some of the water quality parameters are presented. Very easy could be differentiated the bigger Bulgarian tributaries with significant hydrochemical contribution to the Danube river quality – Iskar and Iantra. On the other hand can be noticed the marginal and local impact of the Voinishka and Tzibritza rivers on the Danube water quality. The presented values include as well information about industrial and agricultural activities, urbanization and ecological status of the relevant catchment areas. The significant industrialization along the rivers Iskar and Iantra explain the big values of BOD5 – 4641.5 t for Iskar and 6715.0 t for Iantra (Figure 1). The active agricultural activity in the areas around Ogosta, Iskar, Iantra and Russenski Lom is one of the reasons for enhanced values of nitrate nitrogen and phosphates (Figures 2 and 4) – Ogosta – 596.5 t, Iskar – 820.2 t, Iantra – 695.7 t nitrate nitrogen average per year; Ogosta – 247.6 t, Iskar – 476.9 t, Iantra – 174.1 t phosphates. Intensive stock breeding, untreated municipal waters and not completed nitrification processes explain the higher nitrite concentrations in Iskar, Vit and Iantra rivers – Iskar – 41.9 t, Vit – 16.5 t,Iantra – 58.7 t nitrite nitrogen average per year (Figure 3). As biggest rivers with highest mineral ions concentrations the Iskar and Iantra rivers inflow visibly dominant part of mineral content from Bulgarian side - Iskar – 425165 t, Iantra – 444858 t dissolved materials average per year (Figure 5). Not only anthropogenic but natural erosion processes are a factor for higher suspended matters content in the rivers Iskar – 89125 t, Iantra – 65639 t, Russenski Lom – 71144 t suspended matters average per year (Figure 6).

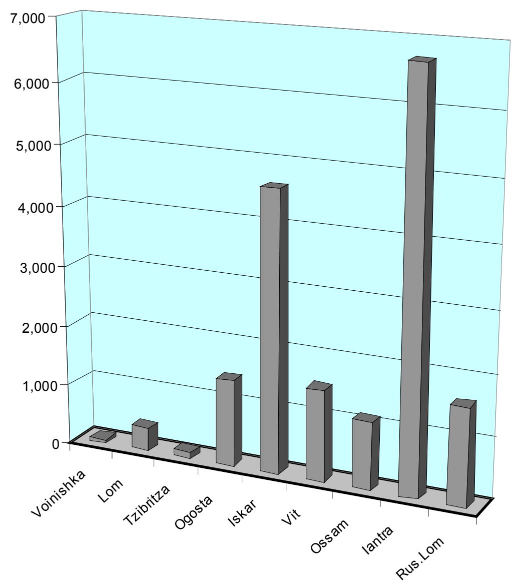

Fig.1 Annual average load of BOD5 in tons inflowing into
the Danube from the Bulgarian tributaries for the period 1996-2000

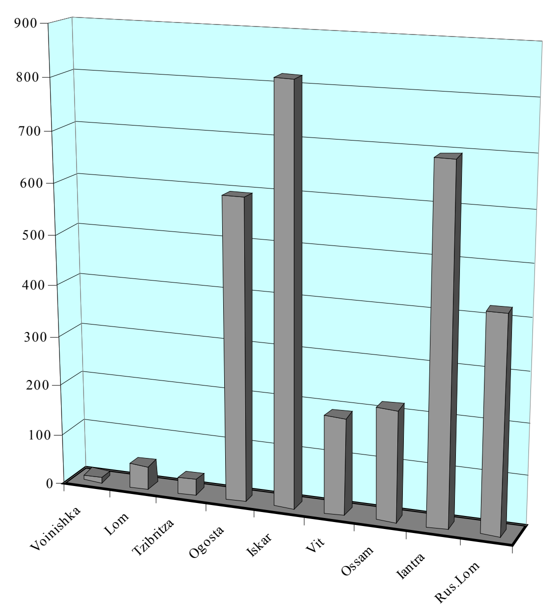

Fig.2 Annual average load of nitrate nitrogen in tons inflowing into
the Danube from the Bulgarian tributaries for the period 1996-2000

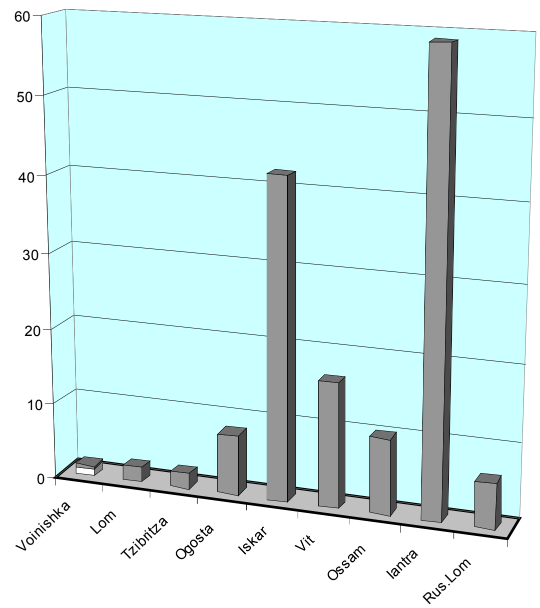

Fig.3 Annual average load of nitrite nitrogen in tons inflowing into the Danube from the Bulgarian tributaries for the period 1996-2000

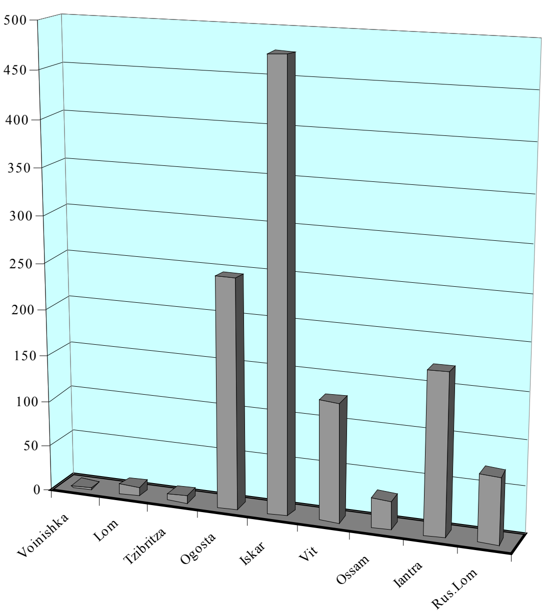

Fig.4 Annual average load of phosphates in tons inflowing into the Danube from the Bulgarian tributaries for the period 1996-2000

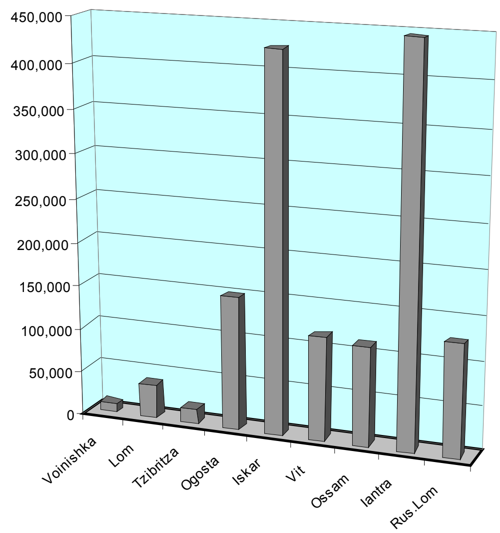

Fig.5 Annual average load of dissolved materials in tons inflowing into the Danube from the Bulgarian tributaries for the period 1996-2000

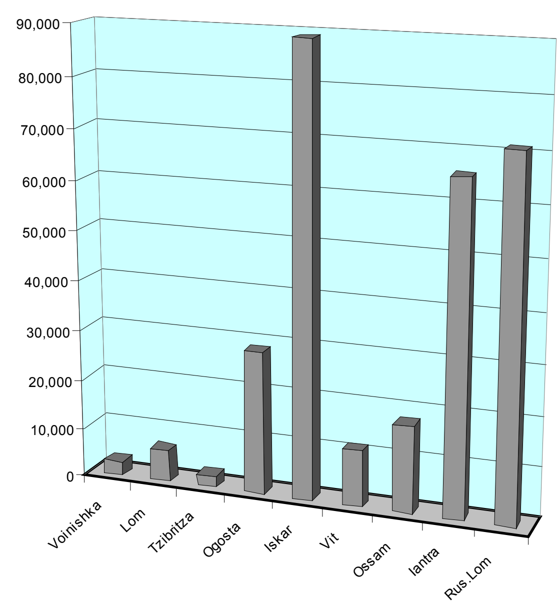

Fig.6 Annual average load of suspended matters in tons inflowing into the Danube from the Bulgarian tributaries for the period 1996-2000

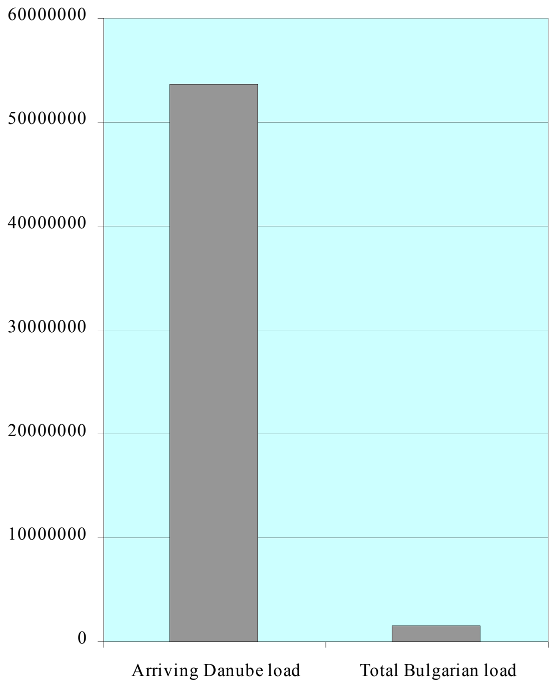

Fig.7 Bulgarian contribution - Dissolved materials in t/year

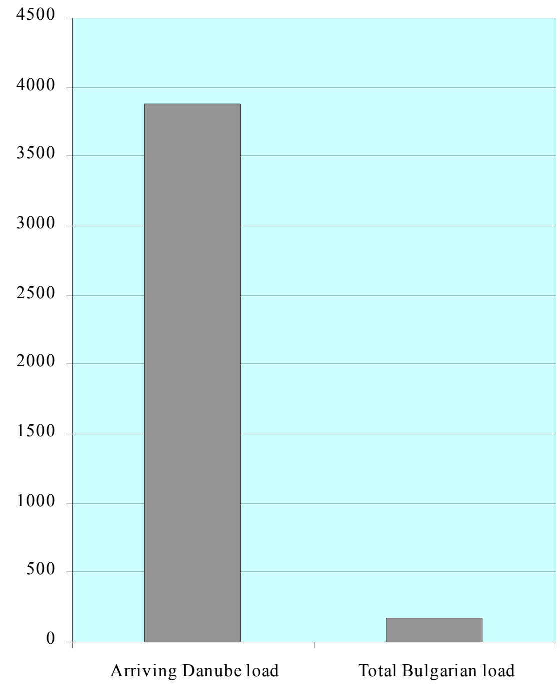

Fig.8 Bulgarian contribution - Nitrite nitrogen in t/year

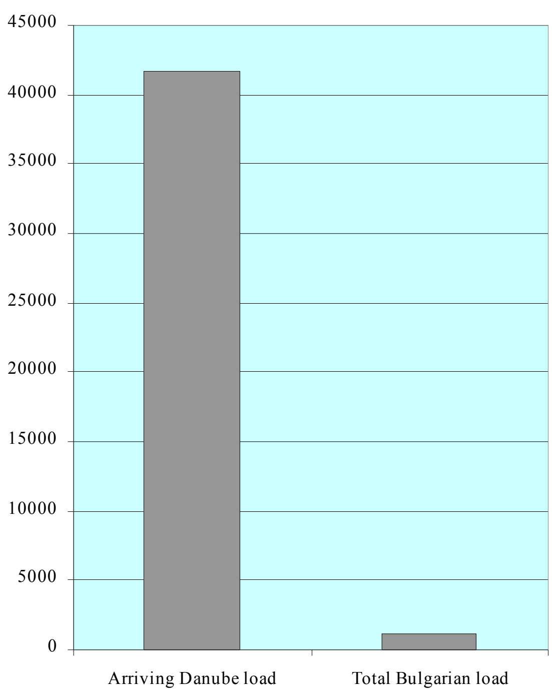

Fig.9 Bulgarian contribution - Ammonium nitrogen in t/year

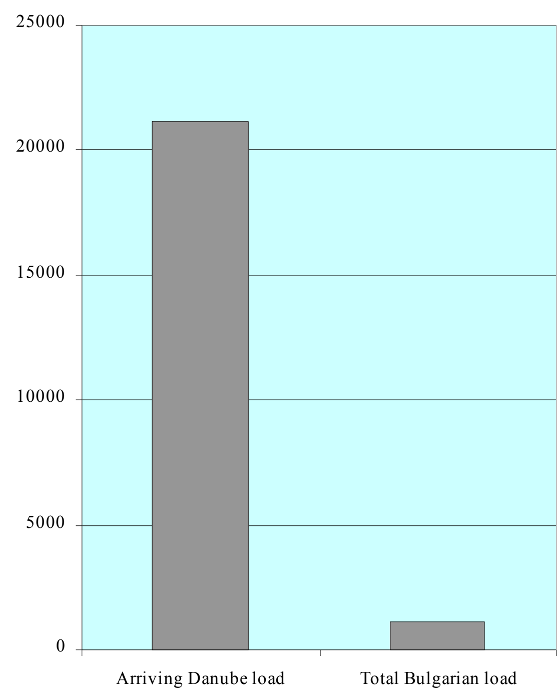

Fig.10 Bulgarian contribution - Phosphates in t/year

There are water quality measurements and assessments at the boundary sectors of the main Danube stream near the village of Novo selo in the Bulgarian part just after Danube enters Bulgarian territory. Because of lack of information the hydrochemical Danube loads for some water quality parameters are calculated on the annual base and the results should be accepted as approximately ones. Comparing the results of the Danube at the beginning of Bulgarian-Romanian sector and the summarized Bulgarian tributaries could be determined the Bulgarian contribution in the increase of the Danube hydrochemical content (Table 2)

Table 2 Bulgarian contribution in forming the Danube hydrochemical loads in %

Parameter	Total Bulgarian load	Arriving Danube load	Bulgarian Contribution
	t	t	%
Ox	22411.92	396317.78	5.66
NO3	3309.11	906935.04	0.36
NO2	174.19	3879.62	4.49
NH4	1225.28	41631.27	2.94
PO4	1151.40	21115.33	5.45
DM	1445131.48	53726724.06	2.69

The Bulgarian Danube tributaries are not big ones and they are located in the lowest part of the Danube river where is expected the hydrochemical content is mainly formed up-stream. Nevertheless the Bulgarian tributaries have some influence that should not be neglected and could be assessed (Figures 7-10). The presented approximately values show that the influence of the different water quality parameters and Bulgarian rivers are different but the total hydrochemical loads contribution annually does not increase several percents. Of coarse the annual hydrochemical loads transported by the Bulgarian Danube tributaries vary essentially in the range of studied period of the last years depending mainly on the hydrological conditions and changing water quality conditions. The presented results should be considered as average ones for the studied period.

References

Ordinance N7, *Parameters and Standards for water quality of the flowing surface waters*, State Paper, 12.12.1986, Sofia, Bulgaria

Tzankov K. (1998): *Methodology for categorization of the river flows on the example of the Mesta river*, Bulgarian Journal of Meteorology and Hydrology, vol.9, no.2, Sofia, Bulgaria.

Blaskova B. (2002) *Tendency of Alteration of the Iskar water quality*, Collection of University of Engineering and Architecture, Sofia, Bulgaria

Rainova V. etc. (2001): *Condition of the Danube midstream in connection with the Bulgarian-Romanian boundary,* Conference on Innovation and Environment protection in the Danube basin, Sofia, Bulgaria.