INFLUENCE OF THE WASTE-WATER OF SZOLNOK ON THE WATER QUALITY OF THE TISZA RIVER

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Abstrakt

The reach of the river Tisza between the mouth of the river Sajó and the town of Szolnok can be characterized by an improvement of the water quality.

In the middle reach of the Tisza a significant pollution load occurs only at Szolnok.

In the vicinity of Szolnok the Tisza is being loaded significantly by the pollution coming from 5 industrial and 4 residential areas, the waste-waters of which show considerable quantitative and qualitative differences. Both the output of the waste-water released and the load of certain polluting components showed a slight increase in the period between 1977 and 1987. Nearly half of the organic matter is being released into the Tisza by the Szolnok Sugar Works during the 100 days' period of sugar processing. The major part of the detergent, ammonium-ion, fat and oil load is of household origin.

The calculated effect of the pollution loah on the Tisza water quality is worth consideration only in the period of sugar processing (September—December). For this reason the deterioration of the water quality has been studied in details only for these periods. The deterioration of the water quality was clearly visible in comparative studies of the water quality in the reaches above and below Szolnok (Tiszaug) based on measurements of organic matter, dissolved oxygen and phosphate-ion concentrations (minimum, average maximum values, distribution curves).

The actual deterioration of the water quality was less expressed than could be expected from calculations due to the self-purification of the river and did not justify its reassignment to lower quality categories for none of the quality parameters.

Introduction

The influence of the waste-waters of the town of Szolnok on the Tisza has been studied on Ciliata already in 1974 by JÓSA (1974). The investigation of the classical parameters in the Tisza reach between Szolnok and Tápé could not demonstrate unequivocally the joint effect of the sewage-water of Szolnok and the waste-water carried by the river of Zagyva (HAMAR et *al.* 1976). However, the detailed investigation of the Tisza longitudinal stretch in 1979, has clearly shown the effect of the waste-water on the basis of increased Clostridium count of the sediment (HEGEDŰS et *al.* 1981) and growth of the Ciliata population (JÓSA 1981).

The water of the Tisza reaching the territory of Hungary is of a comparatively favourable quality (VÍGH 1983). However, it is unfavourably influenced by the polluting materials carried by the Szamos and Sajó rivers. The middle reach of the river can be characterized by an improvement of the water quality. This stretch receives

the highest pollution load in the vicinity of Szolnok. For this reason, the aim of the present work was to elucidate the level of the pollution load in this region and its influence on the water quality of the Tisza. Only the effect of the so-called macro-components of the sewage-water has been studied, other factors modyifing the quality of water (e.g. increase of the receptive bacterial contamination, etc.) have not been dealt with.

Results

1. Trends in the pollution load

In the vicinity of Szolnok nine sources of significant pollution load of the river Tisza can be distinguished (Fig. 1, WAIJANDT 1987a). Their waste-waters show considerable quantitative and qualitative differences. Among the five industrial sources, four (Paper-mill, Animal Marketing and Meat Packing Establishment, Tisza Chemical Works, Fodder Producing Factory) load the Tisza with nearly equal waste-water output the whole year round, contrary to the Szolnok Sugar Works which releases the waste-water mainly in the period of sugar processing between September and December — appr. 100 days a year (waste-water output: 20 000 m^3/d).

The sewage-water of the housing estates in Szolnok are loaded into the Tisza by four transloading stations: at "Gábor Áron" square, "Mártírok" road, "Vörös-hadsereg" road and Tiszaliget. In the last 11 years the output of the sewage-water reaching the receptable (Q) has hardly increased (Fig. 2). However, the organic matter carried by the sewage water has considerably increased in the investigated period.

The total mineral matter load showed an increasing tendency as well. The anion-active detergent content has been increasing only till 1981. A considerable increase in the oil and fat content has been observed till 1984. The annual number of tests carried out varied between 2 and 12 depending on the level of pollution).

From the point of view of pollution reduction by purification, it is important to know the distribution of different polluting components among the sources of

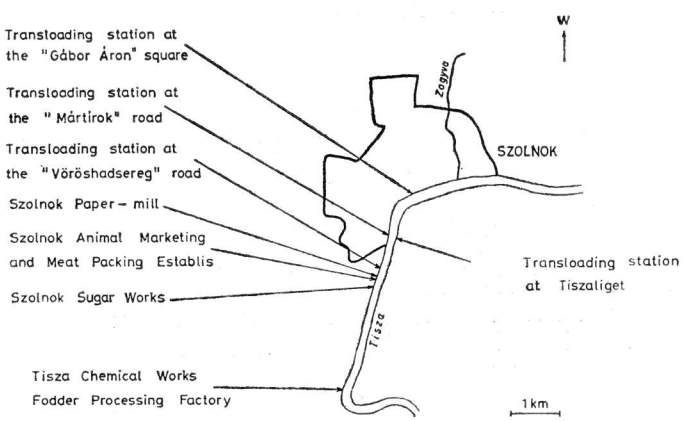

Fig. 1. Sources of waste-water at Szolnok

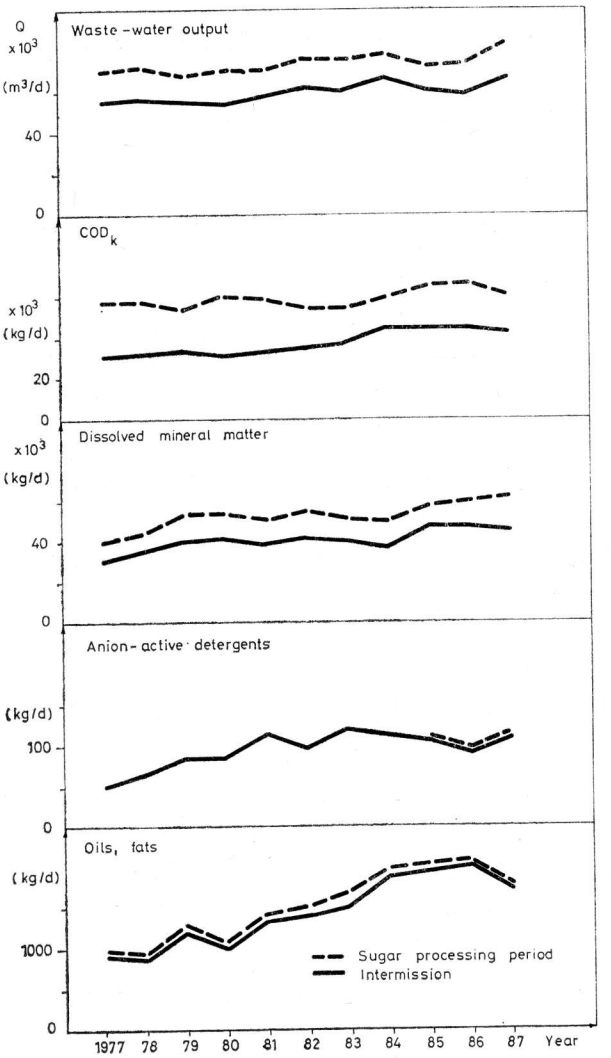

Fig. 2. Waste-water output and pollution load between 1977 and

waste-water. The relative output and various polluting components' content of the sources of waste-water studied are shown in Fig. 3 as the average values for the period between 1983 and 1986 (WAIJANDT 1987b).

From the point of view of the water quality of the Tisza the processing of sugar is a critical period, for which reason the relative values measured in this period are shown in Fig 3. The output and the content of the most important pollutants supplied by the sources studied are expressed on a percentage basis relative to the total waste-water data. The period of sugar processing lasts altogether for 100 days a year, for which reason in the right-hand side of Fig. 3 are shown the ratios of the load originating from the Szolnok Sugar Works (S), as well as the total load from the housing estates (ΣH) relative to the total load (Σ).

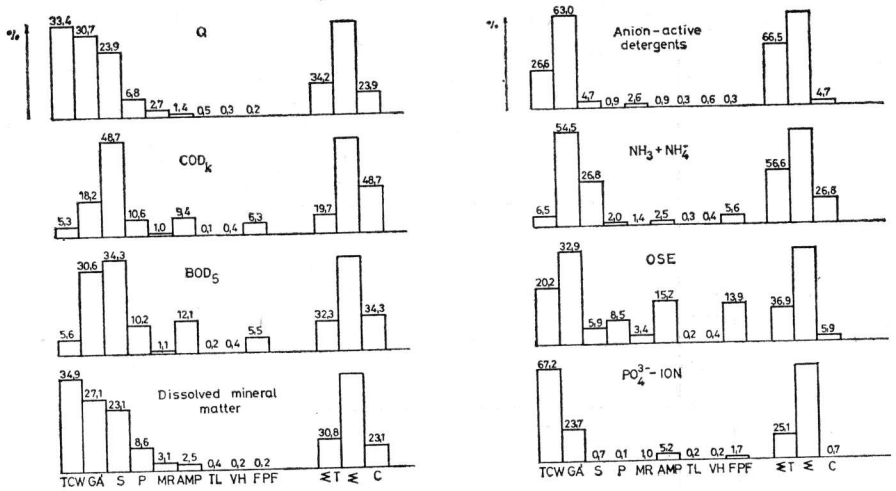

Fig. 3. Output and distribution of the polluting components of the sources of waste-water at Szolnok (average values from measuerements carried out between 1983 and 1986)

The main source of waste-water (25 000 m³/d) is the Tisza Chemical Works, somewhat less is being released into the Tisza by the main source of the household sewage-water — the transloading station at "Gábor Áron" square. Nearly half of the total organic matter (measured by the chromate method and expressed as chemical oxygen demand) is being loaded into the receptacle by the Szolnok Sugar Works. For this reason during a considerable part of the year (appr. 265 days) the organic matter load in the river drops roughly to the half of its maximal value. Similar is the situation with the biological oxygen demand. Except for the sugar processing period the major contribution to the organic matter load, which is biologically easily digested, originates from the sewage-water of the housing estates. It should be mentioned that the COD and BOD_5 load is nearly identical for the biggest and the smallest source of waste-water (Fig. 3)

The relative contributions to the mineral matter load (salts) closely follow the relative waste-water outputs of the sources studied. At the same time this indicates that the mineral matter load is not the most characteristic feature of the Szolnok waste-waters. (Both the Water Company of Szolnok as well as the industrial plants use water from the Tisza to produce drinking water and for industrial purposes respectively).

The major detergent load is being carried into the receptacle by the household sewage water. The same is valid for ammonium ions, too. It can be seen that the ammonium-ion load increases considerably in the Tisza during the sugar processing period.

The oil/fat load in the receptacle which has been measured by the gravimetrical organic solvent extract (OSE) method, originates in the first place from the household sewage-water but there are other sources contributing to the total load as well.

The main source of phosphate is the Tisza Chemical Works. By comparison with the data on detergents it can be concluded that the main part of the phosphate released into the Tisza is not bound to detergents.

2. Calculated effect of the pollution load on the Tisza water quality

From the data presented above it follows that a critical pollution load reaches the Tisza during the sugar processing period (September—December). The situation is better during the rest of the year. The sugar processing period is less favourable from the point of view of the receptacle, too, since at the time the water output of the Tisza decreases (Table 1) and the temperature of the water in the receptacle, which plays an important role in the selfpurification, is lower as well. For these reasons in what follows, the sugar processing period (September—December) and the intermission (January—August) will be discussed separately.

From the output of the waste-water, the pollution load and the massflow of the corresponding components in the Tisza it is possible to calculate the changes in the concentrations of various components under the influence of the pollution load. In the calculations it is presumed that the waste-water released into the Tisza gets completely mixed with the river water. In the calculations the following relation was used (PASZTÓ 1975):

$$C_T^x = \frac{\Sigma Q_W \cdot C_W + Q_T \cdot C_T}{Q_T + \Sigma Q_W}$$

C_T^x — concentration of the component studied in the Tisza after the inflow of the waste-water (g/m³)
C_T — concentration of the component studied in the Tisza before the inflow of the waste-water (g/m³)
Q_W — output of the waste-water (m³/s)
Q_T — flow-rate of the Tisza (m³/s)
C_W — concentration of the component studied in the waste-water (g/m³).

Table 1. *Average values of the Tisza water output and concentrations at Szolnok above the inflow of the Zagyva* (335,4)

year	1983.		1984.		1985.		1986.	
month	1—8	9—12	1—8	9—12	1—8	9—12	1—8	9—12
Q m³/s	587	147	407	382	781	351	659	162
COD_k g/m³	23.3	24.5	28.9	21.6	20.7	15.5	20.4	17.9
BOD_5 g/m³	4.71	3.72	6.26	4.49	5.15	3.88	5.16	4.11
Salts g/m³	267	363	284	289	271	316	261	354
Detergens (anion-active) g/m³	0.042	0.079	0.055	0.055	0.037	0.052	0.043	0.071
NH_4^+-ion g/m³	0.82	1.18	1.37	0.80	1.15	0.87	0.84	0.98
OSE g/m³	—	—	—	—	1.86	1.89	2.00	1.25
PO_3^3-ion g/m³	0.24	0.32	0.27	0.25	0.22	0.26	0.10	0.23
Dissolved oxygen g/m³	9.11	8.64	9.14	9.22	8.97	8.92	9.42	9.68
O_2 saturation (%)	84.6	81.3	78.6	81.3	79.0	80.0	85.3	87.4

In the calculations annual data on the average waste-water output and concentration values in the corresponding periods (sugar processing period and the intermission), as well as the flow-rate and the concentration values of the Tisza water between January—August and September—December, respectively, were used.

In Table 1 the average values of the Tisza flowrate and several important water quality characteristics are given for the above defined two periods. Depending on the Tisza flow-rate fluctuations the water output of the river in the period between September and December constitutes only 24—71% (on the average 40%) of the average value for the period between January and August. The lower values of COD_k and BOD_5 of the Tisza water reaching Szolnok in the sugar processing period have a favourable effect on the water quality. The mineral water content increases slightly in autumn in accordance with the higher water output in this period.

The concentration of detergents is at a satisfactory low level in both periods. The concentration of ammonium-ions shows considerable fluctuations. The dissolved oxygen and oxygen demand values hardly differ in the two periods, in general the values in September—December being slightly more favourable. The concentrations of dissolved phosphate are generally higher in September—December. The increase in the concentration was calculated according to the formula:

$$C = \frac{C_T^x}{C_T} \cdot 100 - 100\,(\%).$$

It can be conluded from Table 2 that in different years in the intermissions between the sugar processing periods (the greater part of the year) a considerable increase in the concentrations have not been observed even if the maximal values are concerned, except for the detergent and phosphate-ion concentrations. However, in the sugar processing period, except for the mineral matter, a considerable increase in the calculated concentrations is observed. It should be mentioned that due to the self-purification of the Tisza, the concentrations of the polluting components, except for the mineral matter, drop to a certain extent even before the complet mixing occurs. However the calculated increase in the concentrations does not indicate such a level in water quality deterioration which would justify its reassignment to a lower quality category as compared to the arriving water. The importance of the calculations is seen in the fact that they provide a basis for the estimations of the actual changes in the water quality.

3. Actual changes in the Tisza water quality

The changes in the water quality of the Tisza caused by the waste-waters of Szolnok should be measured in a reach where a complete mixing of the polluting materials with the river water had already occurred. (The waste-waters flow into the Tisza mainly in the bank regions, and a stretch of a considerable length is required for a complete mixing).

A regular network sampling reach where the mixing is presumably completed is situated at a distance of 75 km to the south from Szolnok at Tiszaug. By comparison of the water quality characteristics measured in this reach and immediately above Szolnok (Table 1), it is possible to estimate the actual changes occurring in the water quality due to the inflow of the waste-waters. (At Szolnok, above the inflow

Table 2. *Calculated increase in concentrations caused by the waste-waters*

	1983.		1984.		1985.		1986.		Min.		average		Max.	
	year								%		%		%	
month	1—8	9—12	1—8	9—12	1—8	9—12	1—8	9—12	1—8	9—12	1—8	9—12	1—8	9—12
COD_k	1.3	6.6	1.7	5.3	1.5	12.4	1.9	17.8	1.3	5.3	1.6	10.5	1.9	17.8
BOD_5	2.2	13.1	2.7	6.8	1.8	9.0	2.3	17.6	1.8	6.8	2.2	11.6	2.3	17.6
Salts	0.16	0.35	0.17	0.25	0.46	0.38	0.28	0.87	0.16	0.25	0.27	0.46	0.46	0.87
Detergents (anion-active)	4.5	9.1	5.6	5.9	3.9	6.4	4.6	8.8	3.9	5.9	4.7	7.5	5.6	9.2
NH_4^+	2.1	7.1	3.0	9.1	1.5	8.22	2.4	9.4	1.5	7.1	2.3	8.4	3.0	9.4
OSE	—	—	—	—	1.4	3.3	1.7	11.3	1.4	3.3	1.5	7.3	1.7	11.3
PO_4^{3-}	5.9	11.7	7.7	8.8	4.6	8.7	15.6	53.2	4.6	8.7	8.5	20.6	15.6	53.2

Table 3. *Calculated and measured average concentrations in the reach at Tiszaug in case of the least favourable pollution load conditions*

	COD_k	BOD_5	Salts	Detergens (anion-active)	NH_4^+-ion	OSE	PO_4^{3-}-ion
				g/m³			
C_T	17.9	4.11	354	0.079	0.98	1.25	0.23
C_T^*	21.1	4.83	357	0.086	1.07	1.39	0.35
$C_{T.UG}$	18.6	4.47	359	0.076	1.03	2.51	0.30
$c_{I.C.}$	25.0	5.0	500	0.20	1.0	—	0.30
quality category at Tiszaug	I.	I.	I.	I.	II.	—	I.

C_T — average concentration in the Tisza reach immediately above Szolnok
C_T^* — calculated average concentration after the inflow of the waste-waters of Szolnok
$C_{T.UG}$ — average concentration measured in the reach at Tiszaug
$C_{I.C.}$ — limiting value for the I. class water quality

of the Zagyva river 52, at Tiszaug 26 midstream samples have been studied every year.)

For every component those least favourable years were selected from Table 2, in which the highest ratios of the pollution load and the massflow in the Tisza for the same component were observed; for the selected years the values of the average concentrations measured above Szolnok and at Tiszaug, as well as the values calculated for Tiszaug according to the method described above for the critical months — September—December, are given in Table 3. Due to the self purification of the river, for most of the components studied (COD_k, BOD_5, detergents, ammonium-ion) the values measured at Tiszaug are lower than the calculated ones.

For the sake of completeness it should be mentioned that pollution load occurs at Martfű, too, between the reaches above the Zagyva mouth and that at Tiszaug but its influence is practically negligible (WAIJANDT 1987a, 1988). The streams flowing into the Tisza between these two reaches (Zagyva, Gerje-Perje, Körös-brook, Peitsik-brook) are relatively polluted and cause further considerable increase in the Tisza load. The pollution brought into the Tisza by these four springs together as compared to the waste-water of Szolnok measures 0,58 for the COD_k value, 0,39 for BOD_5, 7,4 for mineral matter, 1,05 for detergents and 1,1 for phosphate. Thus, during the sugar processing period the load of these springs is not negligible as compared to the pollution released at Szolnok, moreover, for three components it is similar or even exceeding the load at Szolnok.

The average values of the water quality components showing normal distribution, measured in the reaches above Szolnok and at Tiszaug can be compared with the help of the so-called two-sample t-test (FÉLIX, BLAHA 1964, VINCZE 1975).

The average values for COD_k, BOD_5, dissolved mineral matter, anion-active detergent concentration obtained in the four years' period between 1983 and 1986 in the two reaches were identical, with the level of significance corresponding to 95% (The distribution of ammonium-ion and organic solvent extract (OSE) differs from normal, and for this reason the t-test is not applicable to the average values of these components.)

The differences in the water quality of the two reaches can be illustrated in full details with the help of empirical distribution curves (WAIJANDT 1987a, 1988).

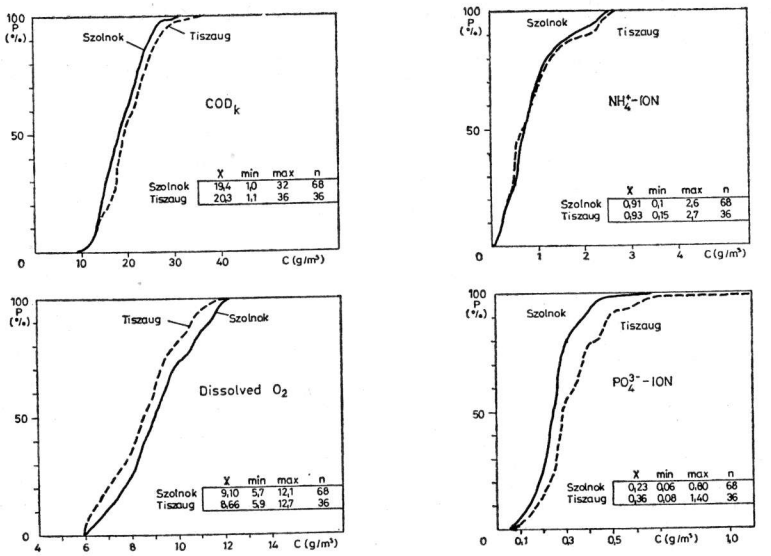

Fig. 4. Empirical distribution curves of the measurements carried out in September—December in the period between 1983 and 1986 above Szolnok and in the reach at Tiszaug

The difference in COD_k values during the critical months (September—December) is not big but still clearly seen (Fig. 4). The dissolved oxygen distribution curves reflect a slightly inferior water quality in the reach at Tiszaug. The ammonium-ion concentrations do not show significant differences. The differences in water quality as far as the dissolved phosphate-ion is concerned were proven both by the average values and the empirical distribution curves. In the nitrate-ion concentration curves no differences were observed, and the average values were in good agreement as well.

In the intermission between the sugar processing periods (the greater part of the year), except for the dissolved phosphate-ion content, the waste-waters of Szolnok do not exert a significant influence on the Tisza water quality (Table 2). In the first eight months of the year due on the one hand to the diluting effect of the higher output of the river, and on the other hand — to the faster rate of the self-purification caused by the higher temperature of the water during the summer months, the effect of the pollution load on the water quality decreases.

Conclusions

— In order to gain more reliable data on the changes in the pollution load from the main sources of waste-water, it is desirable to increase the frequency of the water quality tests.
— The waste-waters of Szolnok as shown by the measurements of the major components do not cause such a deterioration of the Tisza water quality, which would justify its reassignment to a lower quality category. As far as the dissolved mineral matter is concerned, its modifying effect on the water quality is insignificant. The most pronounced changes caused by the waste-waters in the reach below

Szolnok consist in the rise of COD_k values and the concentration of the dissolved phosphate-ions

— The small tributaries of the Tisza in the reach below Szolnok contribute to a significant extent to the deterioration of the water quality in this region.

— From the point of view of the conservation of the water quality of the Tisza, as a first step an adequate purification of the waste-water of the Szolnok Sugar Works seems to be of utmost importance.

The reach of the river Tisza between the mouth of the river Sajó and the town of Szolnok can be characterized by an improvement of the water quality.

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The actual deterioration of the water quality was less expressed than could be expected from calculations due to the self-purification of the river and did not justify its reassignment to lower quality categories for none of the quality parameters.

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Szolnok szennyvizeinek hatása a Tisza vízminőségére

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Kivonat

A sajó torkolata és Szolnok között a folyóra a vízminőség javulása a jellemző. A Tisza, a folyó középső szakaszán csak Szolnoknál kap jelentős szennyezőanyag-terhelést.

A Tiszát Szolnoknál 5 ipari és 4 települési jellegű jelentős kibocsátó szennyezőanyag-terhelése éri, amelyek jelentősen eltérő szennyvízmennyiséggel és minőséggel jellemezhetők. Mind a kibocsátott szennyvíz mennyisége, mind az egyes szennyezőanyag komponensek terhelése kismértékű növekedést mutatott 1977 és 1987 között. A szervesanyag-terhelés csaknem felét a cukorgyártás mintegy 100 napos időszakában a Szolnoki Cukorgyár juttatja a Tiszába. A mosószerek, az ammónium-ion, a zsírok, olajok terhelésének legnagyobb része lakossági eredetű.

A szennyezőanyag-terhelés számított hatása a Tisza vízminőségére csak a cukorgyári kampány (szeptember—december) időszakában említésre méltó. Ezért a létrejött vízminőségromlást kizárólag ezen időszakban vizsgáltuk részletesen. A szervesanyag, az oldott oxigén és a foszfát-ion koncentráció esetében jól megmutatkozott a vízminőségi romlás a Szolnok feletti és Szolnok alatti (tiszaugi) szelvények vízminőségének összehasonlításában (minimum, maximum átlagérték, eloszlásgörbék).

A létrejött vízminőségromlás a folyó öntisztulása miatt kisebb a számítottnál és nem hozott létre vízminőségi osztályváltozást egyetlen vízminőségi komponens esetében sem.

Влияние сточных вод Солнока на качество воды реки Тиса

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Резюме

Для отрезка Тисы между устьем Шайо и Солноком характерно улучшение качества воды. В среднем течении значительное загрязнение поступает в Тису только у Солнока.

В районе Солнока расположено пять источников промышленного и четыре источника бытового характера, значительно загрязняющих Тису, сточные воды которых различаются в качественном и количественном отношении. В период между 1977 г. и 1987 г. наблюдалось известное увеличение как количества сточных вод, так и нагрузки отделных компонентов загрязнения. Почти половина органических веществ поступает в Тису с Сахарного завода в Солноке во время продолжающегося 100 дней процесса производства сахара. Моющие средства, ионы аммония, жиры и масла, поступающие в реку, в обльшинстве своем бытового происхождения.

Рассчеты показывают, что влияние загрязнения на качество воды в Тисе заслуживает специального внимания лишь в период производства сахара. В связи с этим ухудшение качества воды исследовали подробно только в этот период. В сравнительных анализах качества воды (минимальные и максимальные средние значения, кривые распределения) над и под (Тисауг) Солноком доказано ухудшение качества воды в отношении содержания органических веществ, растворенного кислорода, концентрации фосфатных ионов.

Фактическое ухудщение качества воды меньше рассчетного вследствие процесса самоочищения и не приводит к изменению категории качества воды, судя по любому из характеризующих его параметров.

Utjecaj prljave vode na Tisi kod Solnoka

WAIJANDT J.
Directorate of Environmental and Water Conservancy of the Central Tisa region

Abstrakt

Između grla Šajo i grada Solnok kvalitet vode se pobojšava. Reka Tisa je opterećena samo na srednjem otseku sa Solnoškom prljavom vodom.

Kod Solnoka pet fabrika i četiri deo grada ispušta prljavu vodu u reku (vidi sliku), kvalitet količine prljave vode je dosta diferencijalna.

I količina ispuštane prljave vode i komponenti prljave vode pokazali su malo povećanje u periodu 1977 i 1987 god. (2. slika).

Polovine opterećenja sa organskim materijama dolazi iz fabrike šećera (u toku od 100 dana). Deterdženti, azot-joni, masti i ulje proizlazu naročito od stanovništva. (3. slika).

Dejstvo prljave vode za reku je značajan samo za vrijeme kampanja fabrike šećera (sept.—dec.) (2. tabela). Zato je izučen kvarenja kvaliteta vode samo u tom terminu.

Koncentracija organske materije, rastvorenog kiseonika i fosfat-jona je dosta veća u izvađenim primercima ispod Solnoka u poređenju gornjog dela Solnoka (vidi se od grafikona: min., maks., prosećne krive, 4. slika). Kvarenje kvaliteta vode je dosta veća od prirodne regeneracije reke i nije postiglo rezultate da bi podigao kvalitet vode barem sa jednim stepenom.