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HALINA SZYMAŃSKA*

EVALUATION OF WATER QUALITY OF THE VISTULA RIVER AT BIELANY BASED ON THE AUTOMATIC MONITORING STATION DATA

Results of the Vistula River water quality measurements by the AWQMS at Bielany are presented. The data collected manually and automatically in 1973, included 19 pollution parameters. The evaluation of water quality has been based on the indicative and characteristic pollutant concentrations and loads, and their cumulative frequency curves. The extent of pollution from non-point sources in the catchment area encompassed by the Bielany cross-section has also been estimated.

1. INTRODUCTION

In the years 1966–1970, 7 automatic water quality monitoring stations (AWQMS) were constructed on the upper reaches of the Vistula and Odra Rivers, within the Poland 3101 UN DP Project. The stations on Odra River were located at Chałupki, Januszkowice, Wróblin and Wrocław. The stations on the Vistula River were located at Mętków, Bielany and Niepołomice. AWQMS at Mętków controls the upper Vistula River waters influenced by pollutions loads from Upper-Silesian Industrial District (USID) and the town of Oświęcim.

AWQMS "Bielany" controls pollution loads from the USID and Oświęcim, and monitors the quality of water supplying the users situated in the Kraków district. The AWQMS at Niepołomice controls the discharge of pollution loads from the city of Kraków, its factories and the Nowa Huta complex.

Thus, the monitoring stations control cross-sections, particularly important for the protection and development of environment, where permanent measurements and recording of pollution are indispensable. The stations determine the changes in water quality of upper river stretches, the result of different ways of water utilization, self-purification and dilution processes. Stations located on Vistula river are floating stations, equipped with Honeywell W-20 monitors, continuously monitoring the following parameters: water and air temperature, water level, reaction (pH), redox potential (ORP), electrical conductivity, turbidity, chloride concentration, and dissolved oxygen content (DO). Every station can realize 3 programmes: physico-chemical, biological and toxicological.

* Research Institute for Environmental Development, Wrocław Division, Wrocław, Poland.

The physico-chemical programme includes continuous monitoring, daily manual examinations of basic pollution indicators, and extended analyses carried out every two weeks. The biological programme — synchronized with the extended physico-chemical programme includes investigations of bioseston, epiphites and some bacteriological tests.

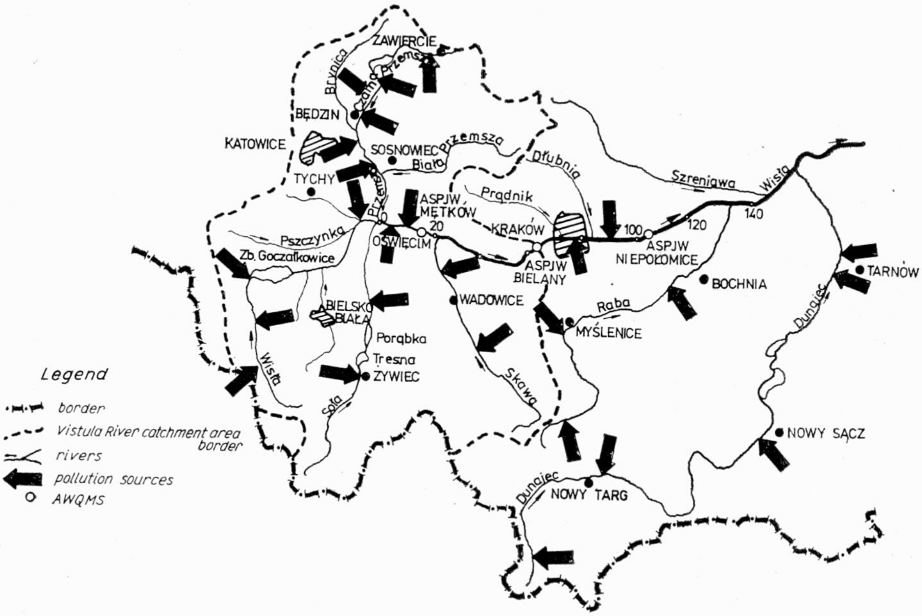


Fig. 1. Hydrographic map of Vistula river catchment area encompassed by the cross-section located in Bielany

Rys. 1. Mapa hydrograficzna zlewni Wisły dla przekroju zlokalizowanego w Bielanach

The aim of toxicological investigations is to estimate directly harmful influence of pollutions, from fish survival, and to determine indirectly the toxic effect of wastewaters from more important pollution sources on selected test organisms representing basic trophic levels of the river water ecosystem.

The cross-section AWQMS "Bielany" on the Vistula river, was investigated in years 1971–1974. In 1971 investigations were carried out manually, automatic physico-chemical and biological tests were started in 1972. At "Niepołomice" cross-section the quality control of the Vistula waters has been carried out manually since 1974.

The results obtained from the separate AWQMS are collected in form of daily raports and elaborated as bulletins of water quality. At the Bielany cross-section automatic monitoring conducted during 1973 included pH, ORP, chloride concentration, conductivity, turbidity, and DO, while colour, alkalinity, total hardness, DO, BOD_5, permanganate value (PV), COD, phenols, ammonia nitrogen, chloride, sulphate, total iron, solid residue, dissolved solids and suspended matter were examined manually. Water samples were collected on workdays at 8 a.m according to published procedures [1].

2. INTERPRETATION OF RESULTS

Results were interpreted according to MAŃCZAK's method [3], based on previously determined: indicative values of concetrations, loads, and characteristic pollution indicators; frequency curves and cumulative curves of concentrations and loads.

Indicative values concentrations were determined by the method proposed by MAŃCZAK [2]. Relationships between the concentration (y in g/m^3) and flow rate (x in m^3/s) were determined using four basic regression equations (a, b, c are equation constants):

$$y = \frac{a}{x} + b, \quad (1)$$

$$y = \frac{a}{x}, \quad (2)$$

$$y = \frac{1}{ax+b}, \quad (3)$$

$$y = \frac{a}{x+b} + c. \quad (4)$$

Indicative concentrations were calculated from the above equations for indicative flows, i.e. average low flow from several decades.

The correlation between pollutant's load (y) and flow (x) was determined by:

$$y = ax^b.$$

The significance of the relationship between flow and concentration of the given parameter was determined by correlation coefficient r_{xy} or r_{kr} by testing at the established level of significance (α) the statistical hypothesis, that this coefficient significantly differs from zero.

According to Cramer the deviation of that coefficient is almost significant at $\alpha = 0.1$, significant at $\alpha = 0.01$ and very significant at $\alpha = 0.001$ [2]. It has been assumed that for biodegradable pollutants $\alpha = 0.2$ and for the others $\alpha = 0.1$, when the deviation of correlation coefficient was almost significant [4].

To eliminate the errors resulting from irregular sampling or heterogeneity of water taken to analysis correlations were calculated for interdependent indicators, i.e. for BOD_5 and PV (permanganate value), DO content and COD, and for conductivity and the content of total mineral dissolved solids (TDS), chlorides and sulphates. These correlations were used to complete the missing results of observations. The measured concentrations, and calculated daily loads allowed to determine the characteristic maxima, minima and mean values in separate months of observations and in the whole year. For loads the monthly and annual sums were calculated [3]. Frequencies and probabilities of concentration and loads were also determined and their total duration in 1973 was calculated. For chlorides and sulphates the load balance was made additionally.

Everyday maximum, mean, and minimum values determined for the parameters measured automatically and recorded on paper tapes, are shown in Fig. 2. These results, were used to determine 9 values for each month: i.e. the highest, mean and the lowest values of the maximum, mean and minimum values recorded in the given month; and 3 values for the whole year i.e. the highest of the highest, mean of the mean and the lowest from the lowest values [9].

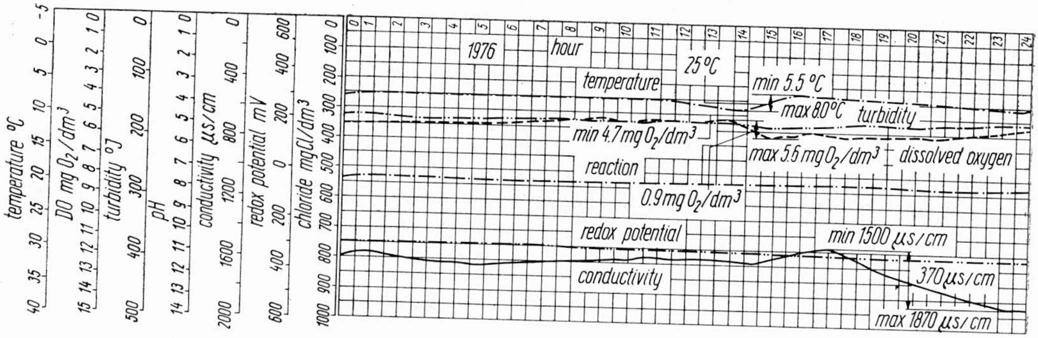


Fig. 2. Record from the W-20 Honeywell monitor at AWQMS Bielany

Rys. 2. Wyniki pomiaru składu wody w Wiśle uzyskane z monitora Honeywell W-20 na ASPJW Bielany—Kraków

The calculated indicative and characteristic concentrations of pollutants enabled the classification of water quality in the Bielany cross-section, according to the criterion of their usefullness for various applications. Water classification was based on water quality standards obligatory in Poland [8]. The estimation of water quality at Bielany cross--section included also unit pollution indicators, determined from the values of annual pollution loads, referred to the drainage area under control, the number of inhibitants, and annual production of pig iron, steel, sulphuric acid, and nitrogen fertilizers. The values of indicators determined in this way will be compared in the consecutive years in order to show the improvement or deterioration of water quality at Bielany AWQMS. In order to preserve the perspective level of river water quality a total wastewater purification degree was also calculated for pollutants produced in the catchment area closed by the Bielany cross-section. It has been established that the Vistula waters, from km 0.0 (Przemsza River mouth) to km 160.6 (Dunajec River mouth), should satisfy the requirements of II class quality, according to the Polish Water Law Standards [12].

3. DISCUSSION OF THE RESULTS FOR 1973

3.1. HYDROLOGICAL CHARACTERISTICS

Vistula River flow rates in 1973 ranged from 39.7 to 387 m³/s. Figure 3 shows daily variations. Increases of flow rates were observed — in March and April, (the spring ice--breaking) on the turn of July, and in February. The lowest flow, observed in 1973 was

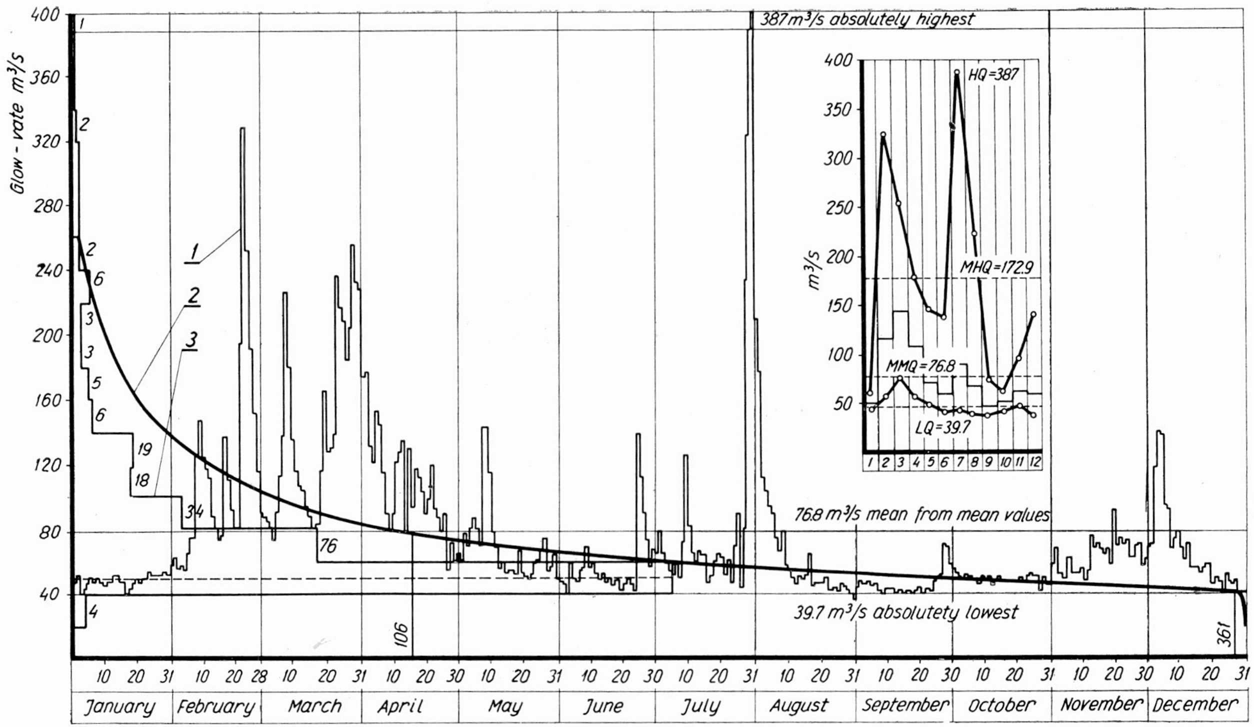
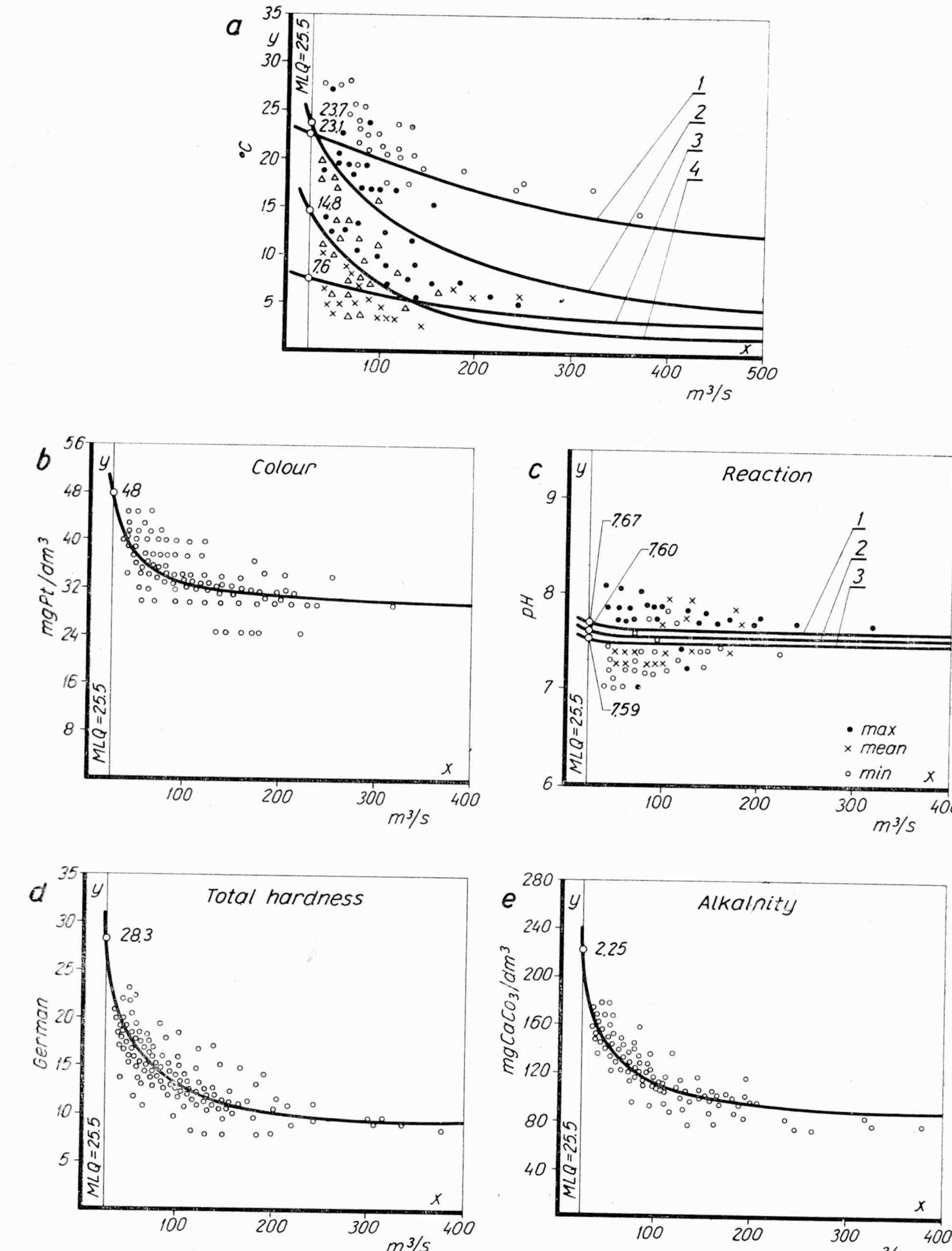


Fig. 3. Daily variations, frequency, and flow rate cumulative curves at Bielany cross-section in 1973;

1 — daily flow rate curve, *2* — flow rate cumulative curve, *3* — flow rate frequency curve

Rys. 3. Wykresy dziennych zmian oraz krzywe częstotliwości i sumy czasów trwania przepływu wody w Wiśle w przekroju Bielany w roku 1973;

1 — dzienne przepływy, *2* — suma czasów trwania przepływu, *3* — częstotliwości przepływu


a
y
°C
MLQ=25.5
23.7
23.1
14.8
7.6
1
2
3
4
x
m³/s
b
Colour
mgPt/dm³
48
c
Reaction
pH
7.67
7.60
7.59
max
mean
min
d
Total hardness
German
28.3
e
Alkalnity
mgCaCO₃/dm³
2.25

1.5 times higher than the mean low indicative *MLQ*, during 1947–1963 amounting to 25.5 m^3/s. The mean annual flow 76.8 m^3/s was slightly lower than the mean annual from several decades *MAQ* being equal to 84.5 m^3/s. Mean indicative flow of the maximum values in 1973 was 173 m^3/s. The values higher than the absolutely lowest flow were recorded in 361 days during 1973.

3.2. CHARACTERISTICS OF THE VISTULA RIVER WATER QUALITY

On account of the extensive research material the characteristics of Vistula River pollution level are shown graphically in Figures 4 to 17, the individual parameters will not be discussed in detail. The figures illustrate characteristic changes in concentrations loads of the separate pollutants i.e. the minimum, mean and the maximum values observed in sucessive months in 1973.

Fig. 4. Concentrations loads of separate pollutants vs. flow–rate

a) ● — spring, o — summer, Δ — autumn, x — winter

$$1-y=\frac{1}{0.0001x+0.04},\ \alpha=0.001,\ n=92\ \text{(summer)};\ 2-y=\frac{1}{0.0004x+0.03},\ \alpha=0.001,\ n=83\ \text{(spring)},\ 3-y=\frac{1}{0.0006x+0.12},\ \alpha=0.001,\ n=69\ \text{(winter)}$$

$$\text{b)}\ y=\frac{495}{x}+29,\ \alpha=0.001,\ n=281$$

c) ● — max, x — mean, o — min

$$1-y=\frac{3.55}{x}+7.53,\ \alpha=0.1,\ n=308;\ 2-y=\frac{3.20}{x}+7.48,\ \alpha=0.1,\ n=308;\ 3-y=\frac{4.68}{x}+7.41,\ \alpha=0.1,\ n=308$$

$$\text{d)}\ y=\frac{524.9}{x}+7.7,\ \alpha=0.001,\ n=277$$

$$\text{e)}\ y=\frac{3836}{x}+7.6,\ \alpha=0.001,\ n=274$$

Rys. 4. Zależności między wskaźnikami zanieczyszczenia i przepływem rzeki Wisły w przekroju Bielany

a) ● — wiosna, o — lato, Δ — jesień, x — zima
c) ● — maksymalny, x — średni, o — minimalny

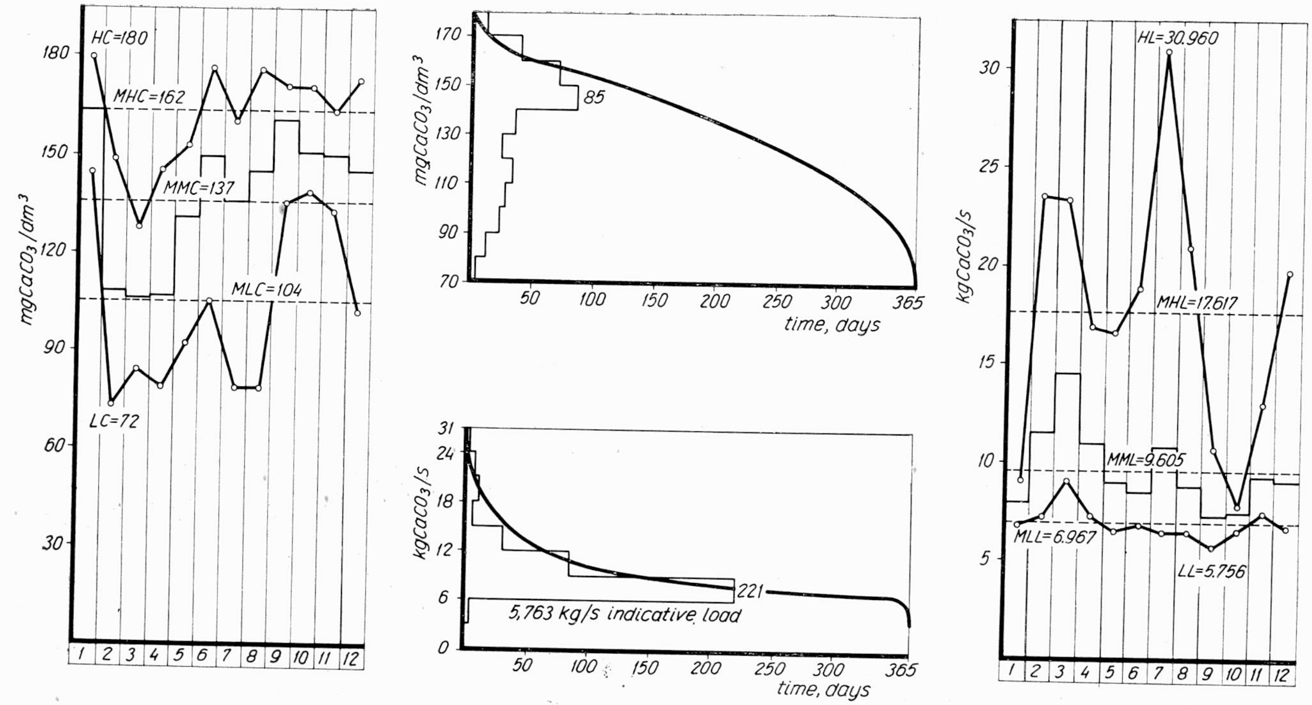


Fig. 5. Characteristic alkalinity concentrations and loads and their frequency and cumulative curves

Rys. 5. Zmiany charakterystycznych wielkości, ładunków i zasadowości oraz krzywe częstości występowania i sumy czasów ich trwania

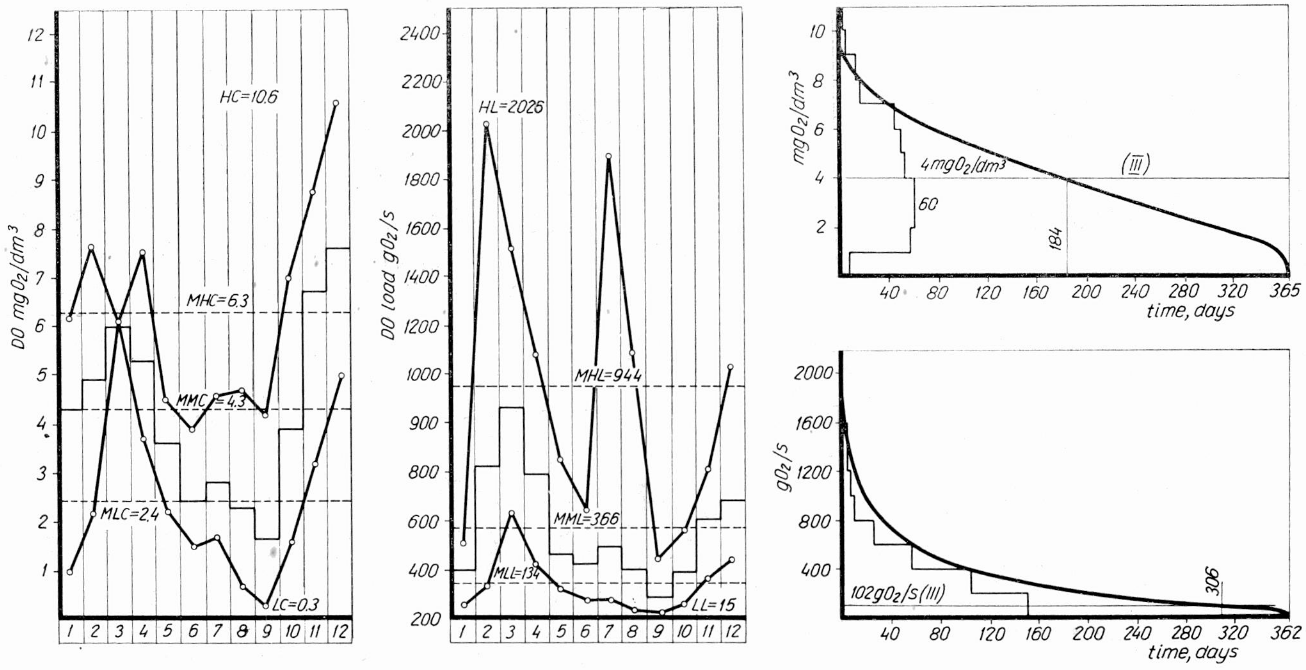
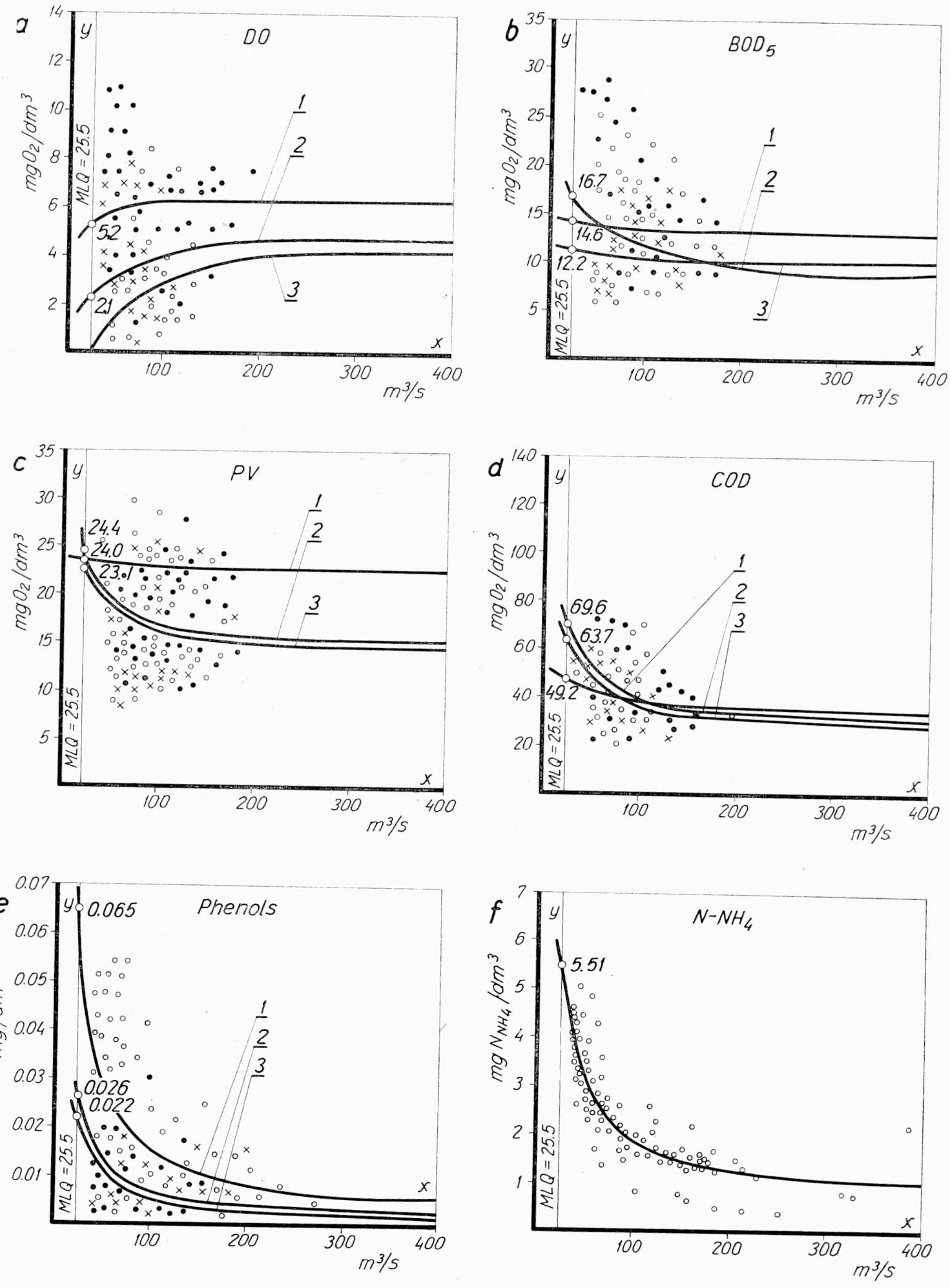


Fig. 6. Characteristic DO concentrations and loads, their frequency and cumulative curves

Rys. 6. Zmiany charakterystycznych zawartości i ładunków rozpuszczonego tlenu oraz krzywe częstości występowania i sumy czasów ich trwania


a
DO
mgO2/dm3
MLQ = 25.5
5.2
2.1
1
2
3
m3/s
b
BOD5
16.7
14.6
12.2
c
PV
24.4
24.0
23.1
d
COD
69.6
63.7
49.2
e
Phenols
mg/dm3
0.065
0.026
0.022
f
N-NH4
mg NNH4/dm3
5.51

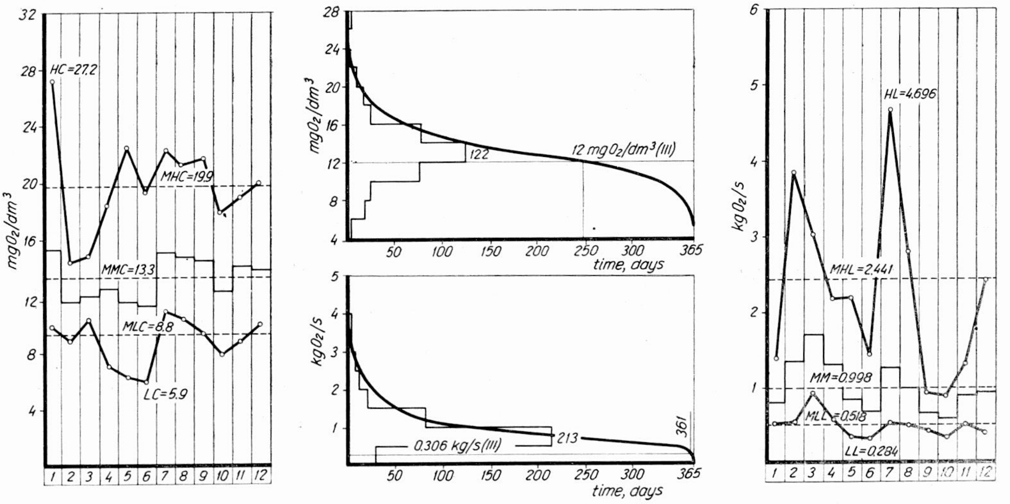


Fig. 8. Characteristic BOD_5 concentrations and loads, their frequency and cumulative curves

Rys. 8. Zmiany charakterystycznych wartości i ładunków BZT_5 oraz krzywe częstości występowania sumy czasów ich trwania

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Fig. 7. Concentration loads of separate pollutants vs. flow–rate at Bielany cross–section

Rys. 7. Zależność między wskaźnikami zanieczyszczenia i przepływem rzeki Wisły w przekroju Bielany

• — t = 0–10 °C, x — t = 10–20°C, 0 — t = 20–30°C

a) $1-y = \frac{-27.7}{x} + 6.3$, $\alpha = 0.1$, $n = 108$; $2-y = \frac{-77.3}{x} + 5.1$, $\alpha = 0.1$, $n = 49$; $3-y = \frac{-143.6}{x} + 5.0$, $\alpha = 0.001$, $n = 56$

b) $1-y = \frac{26.5}{x} + 13.6$, $\alpha = 0.1$, $n = 81$; $2-y = \frac{135.2}{x} + 11.4$, $\alpha = 0.005$, $n = 99$; $3-y = \frac{5.8}{x+65}$, $\alpha = 0.1$, $n = 69$

c) $1-y = \frac{281.7}{x+108} + 21.8$, $\alpha = 0.1$, $n = 73$; $2-y = \frac{267.2}{x} + 14.0$, $\alpha = 0.01$, $n = 84$, $3-y = \frac{186.2}{x} + 15.8$, $\alpha = 0.01$, $n = 103$

d) $1-y = \frac{941}{x} + 33$, $\alpha = 0.001$, $n = 100$; $2-y = \frac{282}{x} + 38$, $\alpha = 0.1$ $n = 72$, $3-y = \frac{865}{x} + 30$, $\alpha = 0.001$. $n = 84$

e) $1-y = \frac{1.661}{x}$, $\alpha = 0.001$, $n = 102$; $2-y = \frac{0.656}{x}$, $\alpha = 0.1$, $n = 70$; $3-y = \frac{0.560}{x}$, $\alpha = 0.001$, $n = 83$

f) $y = \frac{121.97}{x} + 0.73$, $\alpha = 0.001$, $n = 283$

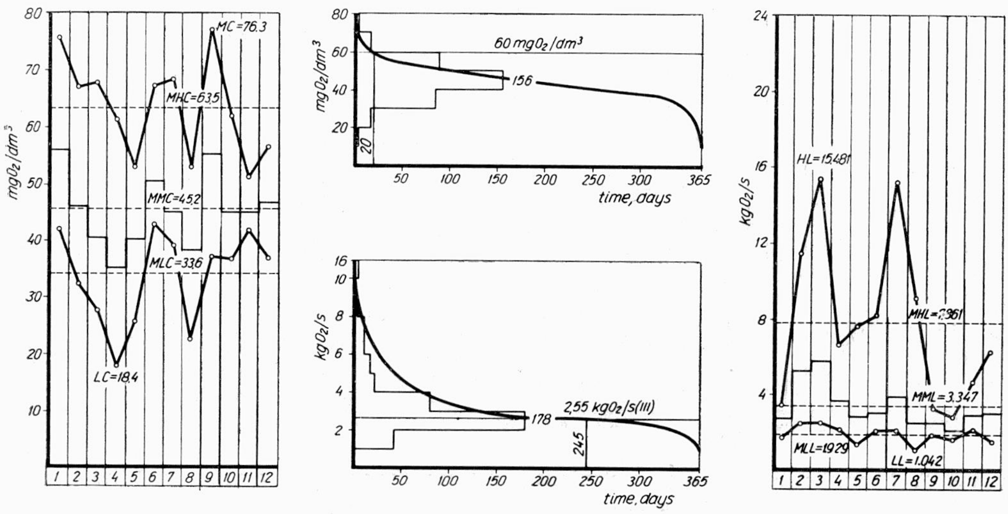


Fig. 9. Characteristic COD concentrations and loads, their frequency and cumulative curves
Rys. 9. Zmiany charakterystycznych wartości i ładunków ChZT oraz krzywe częstości występowania i sumy czasów ich trwania

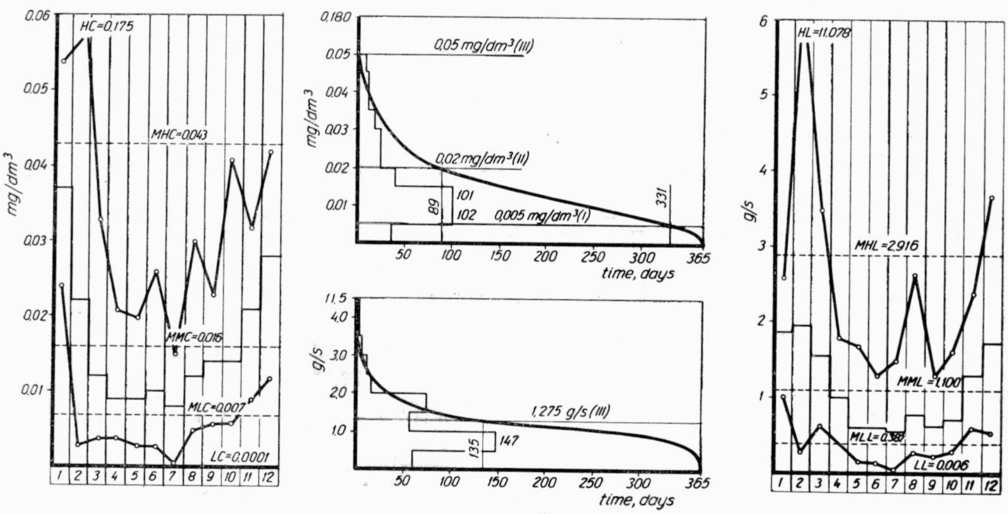


Fig. 10. Characteristic phenols concentrations and loads, their frequency and cumulative curves
Rys. 10. Zmiany charakterystycznych stężeń i ładunków fenoli oraz krzywe częstości występowania i sumy czasów ich trwania

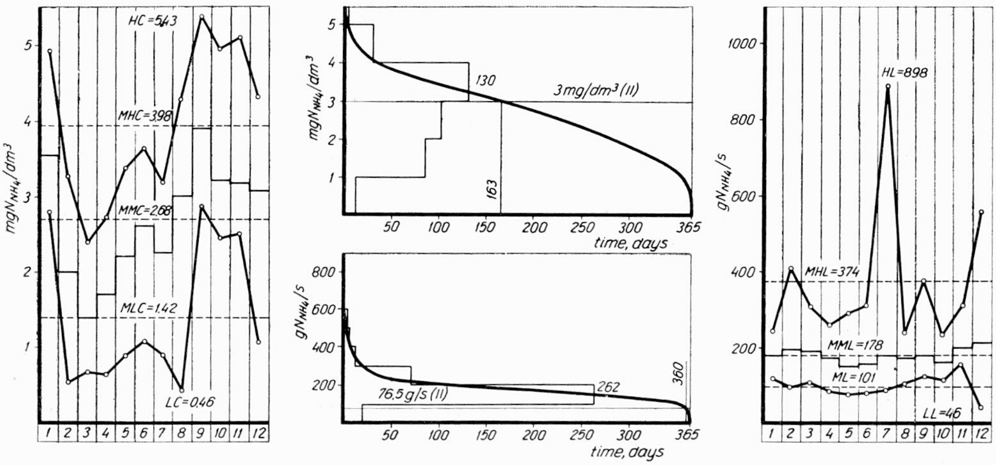


Fig. 11. Characteristic ammonia nitrogen concentrations and loads, their frequency and cumulative curves

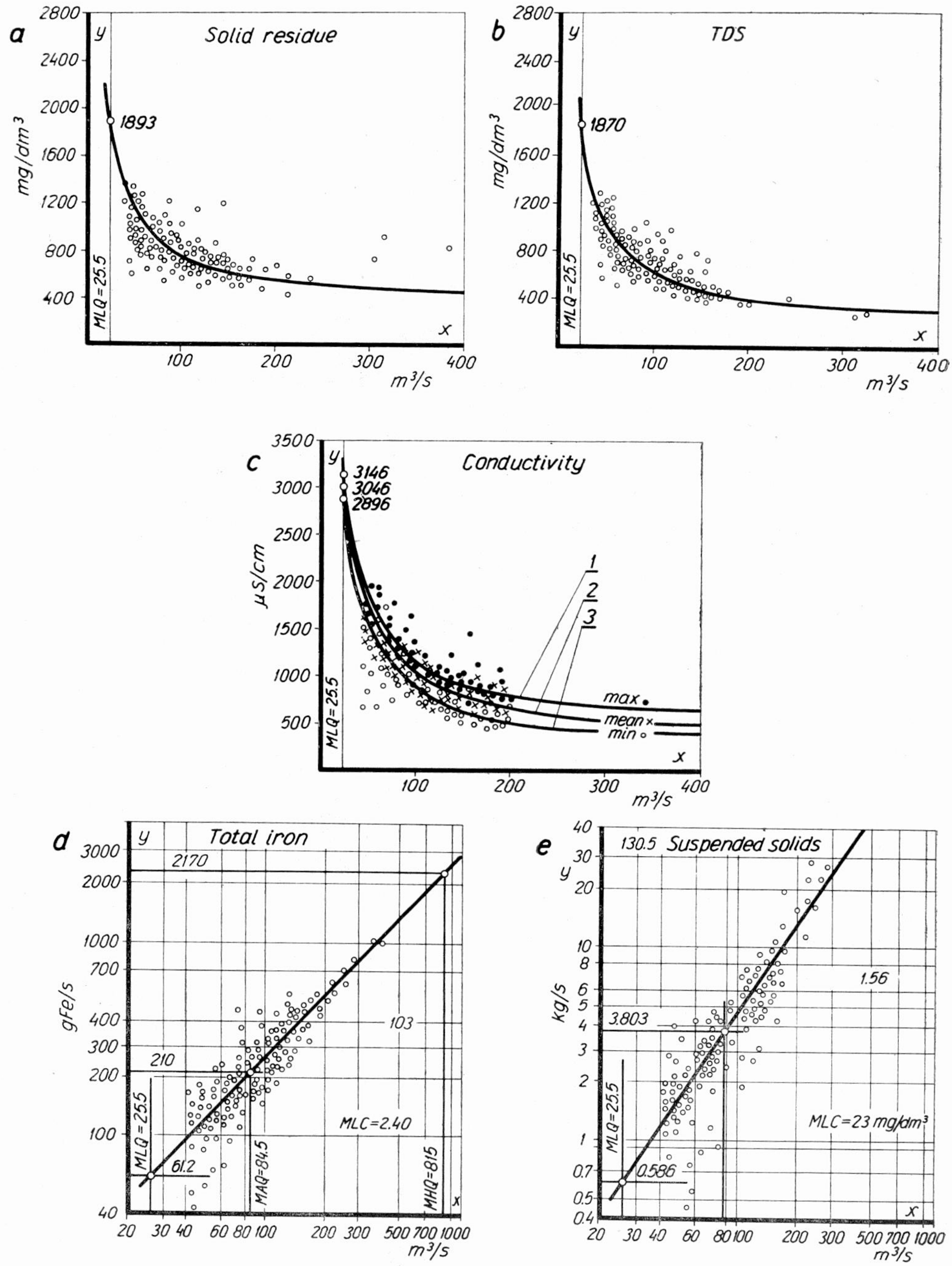
Rys. 11. Zmiany charakterystycznych stężeń i ładunków azotu amonowego oraz krzywe częstości występowania i sumy czasów ich trwania

The values of concentrations and loads for the annual minimum, mean and maximum are marked by three horisontal lines. The figures include also frequency curves, and cumulative curves of annual concentration and load with marked number of days, in which standard values for II and III class of water quality were excceeded. Figures 4, 7 and 12 show illustrate the way in which indicative concentrations (*IC*) were determined from the dependence between the rate of flow and concentration of pollutants or between the load and flow–rate. Comparing the attained *IC* values it can be stated that several parameters significantly exceeded the standards for the III class of water quality, namely: BOD_5 (1.5 times), phenols, chlorides, sulphates, *TDS*; significant oxygen depletion was also observed.

DO contents varied from 0.6 to 10.6 mg O_2/dm^3 (Fig. 6). Minimum values were observed twice: in September, when the Vistula River flow amounted to 48.7 and 50.3 m^3/s and water temperature was 19 and 18.5 °C, respectively.

The maximum occurred in December at 47.0 m^3/s and water temperature 5.9 °C. Annually DO averaged 4.3 mg O_2/dm^3. DO values lower than the acceptable limit occurred in January; in summer (May to September) and several times in October, totalling 181 days, i.e. 49.6% of observations.

Organic pollution of the Vistula River was determined by means of BOD, COD and PV. BOD_5 varied from 5.9 to 27.2 mg O_2/dm^3, the load ranged from 284 to 4696 g O_2/s (Fig. 8). Total annual BOD_5 load was found to be equal to 31 424 t O_2/year. To determine the indicative BOD_5 value, 231 data points were grouped into 3 ranges of water temperatures 0–10 °C, 10–20 °C, 20–30 °C. The BOD_5 indicative concentrations (*IC*) amounting to 12.2, 14.6, and 16.7 mg O_2/dm^3 exceeded the III class' 12.0 mg O_2/dm^3 standard. In general, the BOD values exceeded this limit in 248 cases, i.e. in 67.9% of analyses.


a
Solid residue
mg/dm³
1893
MLQ=25.5
m³/s
b
TDS
1870
c
Conductivity
μS/cm
3146
3046
2896
1
2
3
max •
mean ×
min ○
d
Total iron
gFe/s
2170
210
61.2
103
MLC=2.40
MAQ=84.5
MHQ=815
e
130.5 Suspended solids
kg/s
3.803
0.586
1.56
MLC=23 mg/dm³

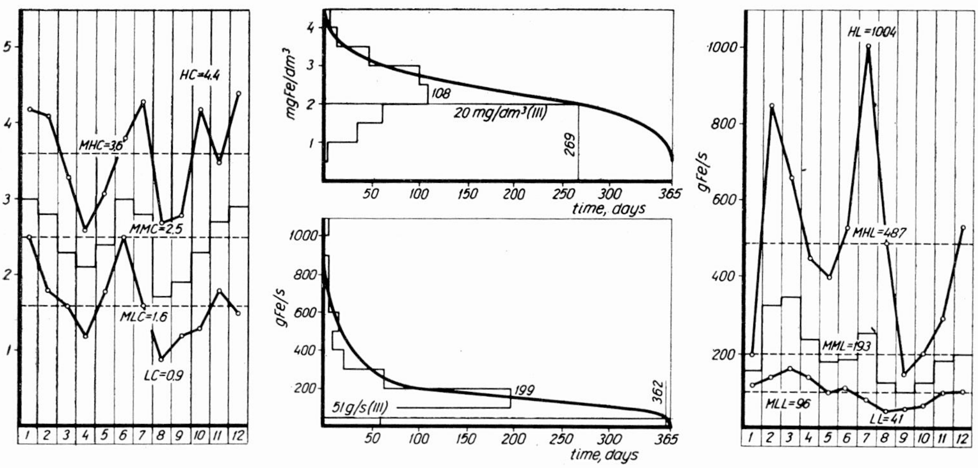


Fig. 13. Characteristic iron contents and loads, their frequency and cumulative curves

Rys. 13. Zmiany charakterystycznych zawartości i ładunków żelaza oraz krzywe częstości występowania i sumy czasów ich trwania

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Fig. 12. Concentrations loads of separate pollutants vs. flow-rate at Bielany cross-section

Rys. 12. Zależności między wskaźnikami zanieczyszczenia i przepływem rzeki Wisły w przekroju Bielany

a) $y = \frac{39451}{x} + 385, \ \alpha = 0.001, \ n = 276$

b) $y = \frac{42933}{x} + 187, \ \alpha = 0.001, \ n = 276$

c) $1 - y = \frac{67968}{x} + 481, \ \alpha = 0.001, \ n = 197;$

$2 - y = \frac{69269}{x} + 329, \ \alpha = 0.001, \ n = 198;$

$3 - y = \frac{68142}{x} + 223, \ \alpha = 0.001, \ n = 197$

d) $y = 2.18x$; e) $y = 3.75\ x$

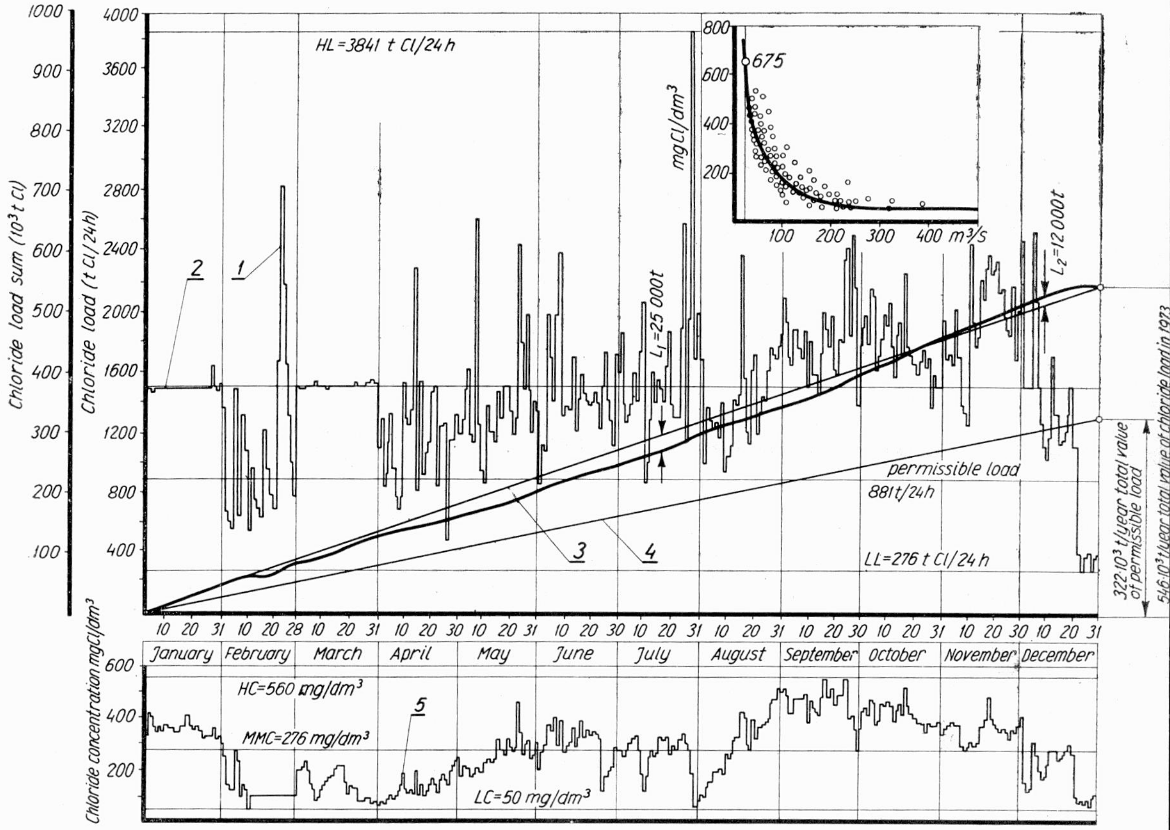

Fig. 14. Vistula River chlorides balance at Bielany in 1973

$y = \frac{17163}{x} + 2$, $\alpha = 0.001$, $n = 296$; *1* — daily chloride load curve, *2* — MML = 1494 Cl/24h, *3* — equalized load line, *4* — permissible load summation line, *5* — daily chloride concentration curve

Rys. 14. Bilans chlorków rzeki Wisły w przekroju Bielany w roku 1973

1 — dzienne obciążenie chlorkami,
2 — MML = 1494 Cl/24h,
3 — wyrównana linia obciążenia,
4 — sumaryczna linia dopuszczalnego obciążenia,
5 — krzywe dziennego stężenia chlorków

PV — permanganate demand value varied from 9.6 to 36.8 mg/dm³. The *IC* values in mg O_2dm³ amounted to 24.4; 24.0 and 23.1, respectively, including the water temperature effects, for temperature ranges: 0–10 °C; 10–20 °C; 20–30 °C (Fig. 7). All of these values are below the III class standards.

COD varied from 18.4 to 76.3 mg O_2/dm³. The values 40–50 mg O_2/dm³ occurred most frequently (156 days), as shown in Fig. 9. The *IC* values, calculated from the concentration-versus-flow-curves are 69.6 mg O_2/dm³ (0–10 °C), 49.2 mg O_2/dm³ (10–20 °C), and 63.7 mg O_2/dm³ (20–30 °C).

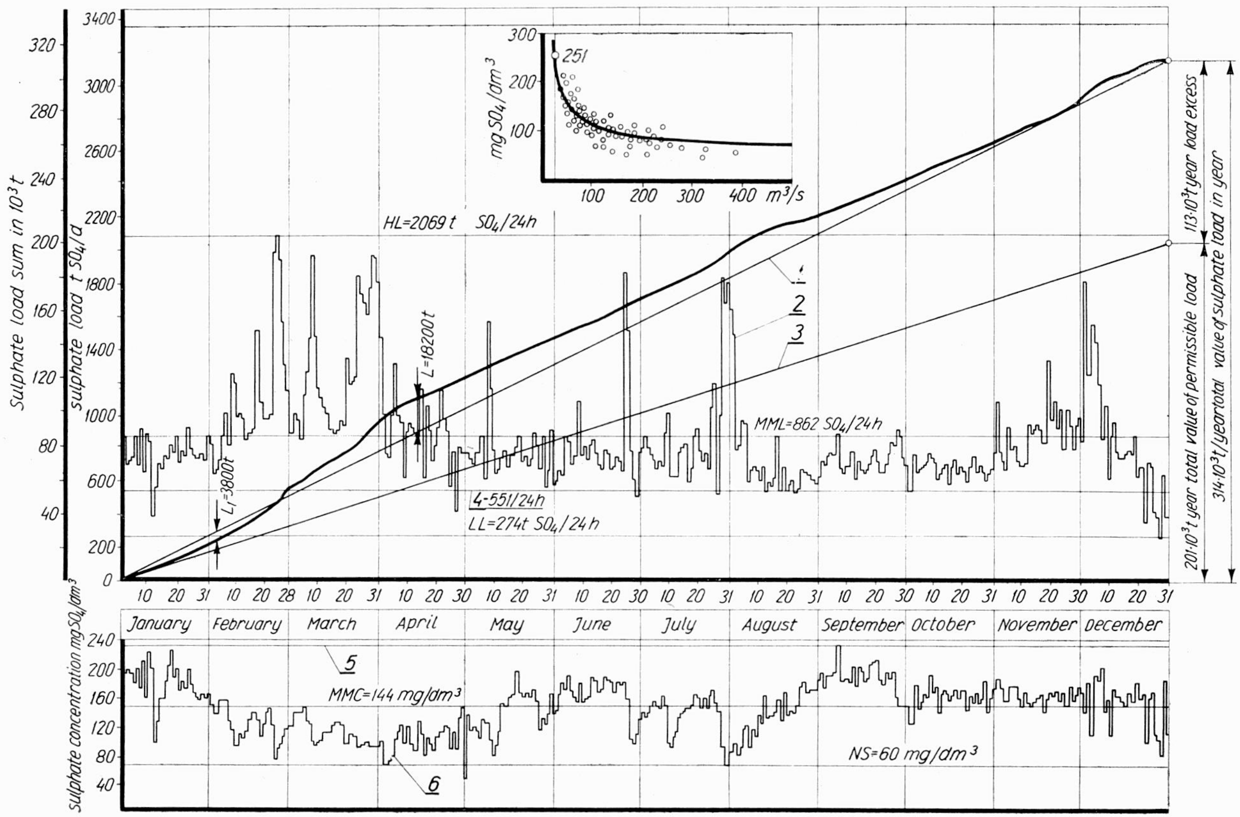

Fig. 15. The sulphate balance at Bielany, in 1973

$y = \frac{4587}{x} + 71$, $\alpha = 0.001$, $n = 280$; *1* — equalized load, *2* — sulphate load curve, *3* — summation line of permissible sulphate load, *4* — permissible load, *5* — HC = 229 mg/dm^3, *6* — daily sulphate concentration curve

Rys. 15. Bilans siarczanów rzeki Wisły w przekroju Bielany w roku 1973

1 — wyrównana linia obciążenia, *2* — krzywa obciążenia siarczanami, *3* — linia sumaryczna dopuszczalnego obciążenia siarczanami, *4* — dopuszczalne obciążenie, *5* — HC = 229 mg/dm^3, *6* — krzywe dziennego stężenia siarczanów

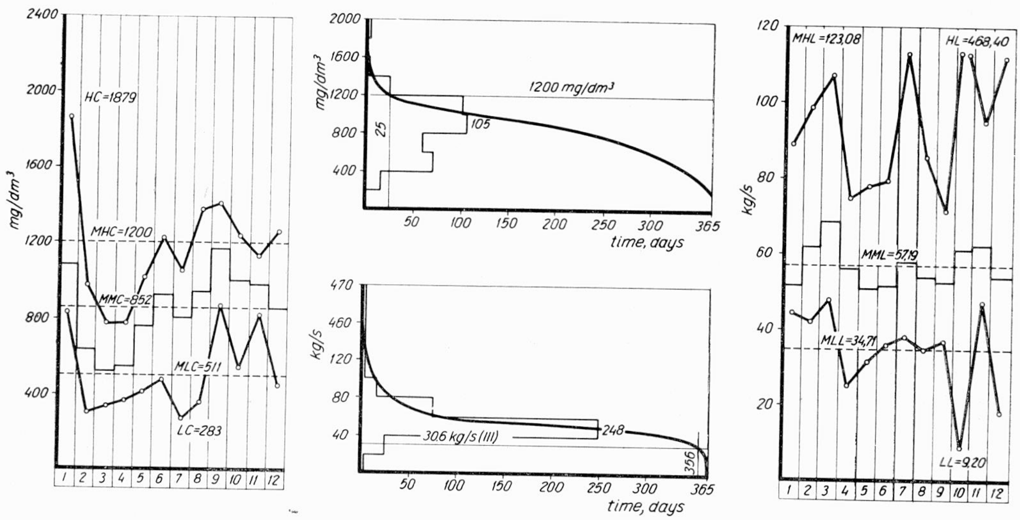

Fig. 16. Characteristic dissolved matter values and loads, their frequency and cumulative curves

Rys. 16. Zmiany charakterystycznych zawartości i ładunków związków rozpuszczonych oraz krzywe częstości występowania i sumy czasów ich trwania

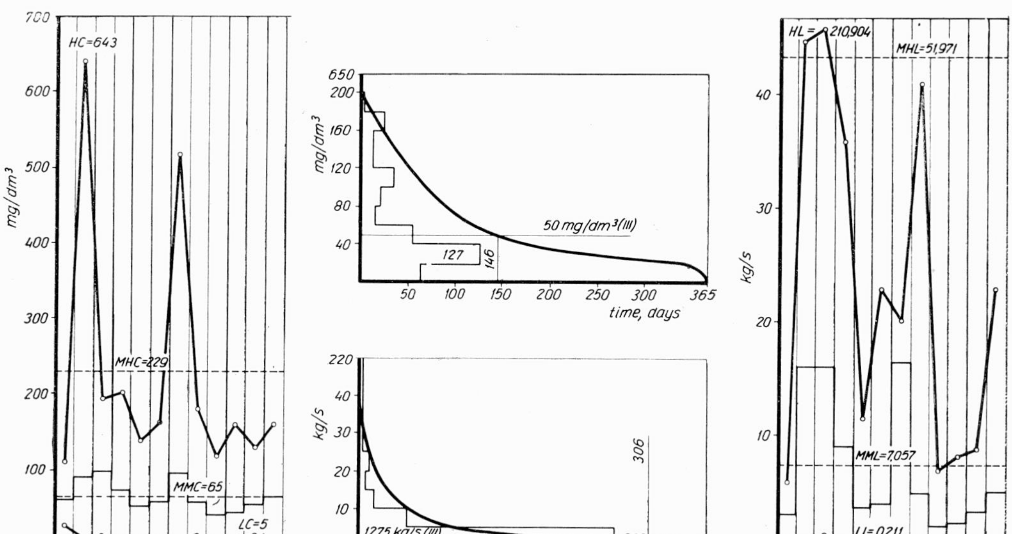

Fig. 17. Characteristic suspended solids amounts and loads, their frequency and cumulative curves

Rys. 17. Zmiany charakterystycznych ilości i ładunków zawiesin oraz krzywe częstości występowania i sumy czasów ich trwania

Concentrations of phenolic compounds varied from 0.0001 to 0.175 mg/dm^3 (Fig. 10); the loads changed from 0.006 to 11.078 g/s. At Bielany the total annual phenol load in the Vistula River was 346.6 t/a. The *IC* values at the temperature ranges: 0–10°C, 10–20°C and 20–30°C were: 0.065, 0.026 and 0.022 mg/dm^3, respectively, (Fig. 7). The corresponding loads were: 1.657, 0.663 and 0.561 g/s. The $IC = 0.065$ mg/dm^3 for 0–10 °C exceeds the III class standard, the remaing values exceed the II class' standard.

The values 0.005 to 0.010 mg/dm^3 (102 days) and 0.010 to 0.015 mg/dm^3 (101 days) were most frequently registered. For 147 days the load carried by Vistula equalled 0.5–1.0 g/s.

Colour intensity data indicate that at Bielany highly coloured water resulting mainly from the high iron and suspended solids (SS) content appeared 309 times (84.7% of annual observations in 1973). Minimum colour was found in April and August, maximum in January, February, August and September. The *IC* value, equal to 48 mg Pt/dm^3, exceeds slightly the natural colour, determined by Mańczak's method as the average from 12 lowest results. This value amounts to 31 mg of Pt/dm^3 (Fig. 4).

Iron concentration exceeding 2.0 mg of Fe/dm^3 occurred 269 times a year, i.e. in 73.7% of observations (Fig. 13). The indicative concentration (*IC*), established from the flow versus iron load, is 2.4 mg of Fe/dm^3, as being the quotient of 61.2 g of Fe/s and $MLQ = 25.5$ m^3/s.

Table 1

General characteristic of Vistula River water quality at Bielany AWQMS cross-section, in 1973, expressed by the time the values exceeded legislated standards for III class of water quality

Pollution indicator	Units	The norm III class standard	Manual programme			Automatic programme		
			No. of observations	standard of days	exceeded % days	No. of observations	standard of days	oxceeded % day
Water temperature	°C	26.0	—	—	—	365	4	1.10
Colour	mg Pt/dm^3	31.0	365	309	84.7	—	—	—
Reaction	pH	6.0–9.0	—	—	—	365	0	0
Alkalinity	mgCaCO$_3$/dm^3	no standard	365	—	—	—	—	—
Total hardness	°n	39.2	365	0	0	—	—	—
Dissolved oxygen	mg O$_2$/dm^3	4.0	—	—	—	365	181	49.6
BOD5	mg O$_2$/dm^3	12.0	365	248	67.9	—	—	—
Permanganate value	mg O$_2$/dm^3	30.0	365	4	1.10	—	—	—
COD	mg O$_2$/dm^3	100.0	365	0	0	—	—	—
Phenol	mg/dm^3	0.05	365	3	0.83	—	—	—
Ammonia nitrogen	mgNNH$_4$/dm^3	6.0	365	0	0	—	—	—
Conductivity	uS/dm^3	no standard	—	—	—	365	—	—
Sulphate	mgSO$_4$/dm^3	250	365	0	0	—	—	—
Total iron	mg Fe/dm^3	2.0	365	269	73.7	—	—	—
Chloride	mg Cl/dm^3	400	365	60	16.4	—	—	—
Solid residue	mg/dm^3	no standard	365	—	—	—	—	—
Dissolved compounds	mg/dm^3	1200	365	25	6.9	—	—	—
Turbidity	°J	no standard	—	—	—	365	—	—
Suspended solids	mg/dm^3	50	365	146	40.0	—	—	—

Significant salinity of the river water was also stated. It was expressed by chlorides concentrations, ranging from 50 to 560 mg Cl^-/dm^3 and 3196 to 44460 g Cl^-/s. The *IC* values determined as 675 mg Cl^-/dm^3 and 17212 g Cl^-/s significantly exceed the III class' water quality standard (400 mg Cl^-/dm^3 i.e. 10200 g Cl/s). In 60 cases (16.4% of observations) the chlorides exceeded the 400 mg Cl^-/dm^3 concentration; as to the loads, the standard was exceeded in 334 cases.

Sulphates varied between 60 and 229 mg $SO_4^=/dm^3$ and 3167 to 23944 g $SO_4^=/s$. The load corresponding to the indicative *IC* (251 mg SO_4/dm^3), amounted to 64 g $SO_4^=/dm^3$ (Fig. 15). These values slightly exceed the III class standard (250 mg $SO_4^=/dm^3$).

Chlorides and sulphates balance is presented in Figs 14 and 15. Assuming that the flow $MLQ = 25.5$ m^3/s and that permissible concentrations 400 mg Cl/dm^3 and 250 mg $SO_4^=/dm^3$, respectively, were constant throughout the year, the total annual loads allowed for discharge in 1973 were calculated to be 322000 t Cl/a. and 201 000 tons $SO_4^=/a$. As the cumulative chlorides loads were 546 000 Cl^- tons/a and 314 000 tons $SO_4^=/a$, an excess load discharged is calculated as 224 000 tons Cl^-/a and 113 000 tons $SO_4^=/a$.

TDS concentrations varied from 283 to 1879 mg/dm^3(Fig. 16), the *IC* equalled 1870 mg/dm^3 (Fig. 12). This corresponds to a significant increase of *IC* over the permissible III class standard of 1200 mg/dm^3.

Another measure of total disolved solids (*TDS*) is the conductivity, which varied between 280 and 2191 μs/cm. The indicative values were defined from the maximum, mean and minimum data points recorded throughout the year; their values being: 3146, 3046 and 2896 μs/cm (Fig. 12). The general summary of these considerations is presented in Table 1 which shows duration of concentrations exceeding the III class water quality.

4. SUMMARY

The water quality of Vistula River at Bielany may be also defined in terms of a total level of treatment (*TLT*) of all wastewaters originating in the catchment area above this cross-section. The value of *TLT* defines the required reduction of pollutants in order to attain the water quality at Bielany, corresponding to the II class standards:

$$(\%)\ TLT = \frac{IC-PC}{IC} \cdot 100, \tag{6}$$

where: *IC* — is (the indicative) and *PC* — (the permissible II class) concentration of a pollutant (mg/dm^3).

In case of suspended solids the *IC* was taken as an average high flow-rate from several decades, i.e. 815 m^3/s. The values are presented in Table 2.

The quality of Vistula River waters may also be defined in terms of the aerial pollution load as presented in Table 3.

From 1972 to 1973 the Vistula River water quality at Bielany deteriorated [9]. This refers to all physico-chemical indicators. The colour of the water increased from 39 to 48 mg Pt/dm^3, the solid residue from 1095 to 1893 mg/dm^3.

Table 2

Total level of treatment wastewaters in the Vistula catchment area above Bielany

Pollutant	*TLT* removal (%)
BOD_5	52.0
PV	18.0
COD	13.8
Phenols	69.2
Ammonia nitrogen	45.5
Total iron	37.5
Chloride	55.5
Sulphate	20.3
Chlorides + Sulphates	46.0
TDS	46.5
Suspended solids	74.0

Table 3

Areal pollution loads to Vistula river at Bielany

Pollutant	Areal pollution load	
	t/km² year	kg/cap. year
BOD_5	4.12 O_2	19.5 O_2
Permangenate value,	5.82 O	27.6 O_2
COD	13.78 O_2	65.4 O_2
Phenols	0.045	0.213
Alkalinity	39.67 $CaCO_3$	188 $CaCO_3$
Ammonia nitrogen	0.703 N_{NH_4}	3.3 N_{NH_4}
Total iron	0.796	3.8
Chloride	71.54 Cl	33.9 Cl
Sulphate	41.15 SO_4	19.5 SO_4
Solid residue	264.23	1250
Dissolved compounds	236.36	1120
Suspended solids	28.96	130

At the same time the increase of pollution by organic compounds was observed. Biochemical oxygen demand (BOD_5) increased from 15.5 to 16.7 mg O_2/dm^3, permanganate value from 19.5 to 24.4 mg O_2/dm^3 and COD from 68.0 to 69.6 mg O_2/dm^3.

The salinity also increased. Sulphates concentration in 1972 was 199, and in 1973 — — 251 mg $SO_4^{=}/dm^3$. The content of nitrogenous compounds increased from 4.16 to 5.51 mg/N_{NH_3} /dm^3, and phenol concentration from 0.015 to 0.065 mg/dm^3. The calcium carbonate amount carried by the river increased from 166 to 226 mg $CaCO_3/dm^3$.

STOPIEŃ ZANIECZYSZCZENIA RZEKI WISŁY NA PODSTAWIE WYNIKÓW AUTOMATYCZNEJ STACJI POMIARU JAKOŚCI WODY W BIELANACH

Artykuł omawia wyniki badań stanu czystości wód rzeki Wisły uzyskane z automatycznej stacji pomiaru jakości wody w Bielanach. Badania, prowadzone w roku 1973, objęły 19 parametrów zanieczyszczenia. Ocenę poziomu czystości wód Wisły sporządzono na podstawie miarodajnych i charakterystycznych stężeń i ładunków zanieczyszczeń oraz krzywych sum czasów ich trwania. Określono również wielkości zanieczyszczeń w obszarze zlewni rzeki zamkniętej przekrojem w Bielanach.

VERUNREINIGUNSGRAD DES FLUSSES WISŁA ANHAND ERGEBNISSEN DER AUTOMATISCHEN MESSTATION DER WASSERGÜTE IN BIELANY

Der Artikel bespricht Forschungsergebnisse des Wasserreinigungstandes des Flusses Wisła, anhand der automatischen Messtation der Wassergüte in Bielany.

Die im Jahre 1973 durchgeführten Forschungen umfassten 19 Verunreinigungsparameter. Die Abschätzung des Wasserreinigungsstandes wurde anhand der massgebenden und charakteristischen Konzentrationen, Verunreinigungsladungen und ihrer Dauerline aufgesetzt. Es wird auch die Verunreinigungsgrösse des Flussgebietes mit dem versperrten Querschnitt in Bielany, bezeichnet.

СТЕПЕНЬ ЗАГРЯЗНЕНИЯ РЕКИ ВИСЛЫ ПО РЕЗУЛЬТАТАМ, ОТМЕЧЕННЫМ АВТОМАТИЧЕСКОЙ УСТАНОВКОЙ ДЛЯ ИЗМЕРЕНИЯ КАЧЕСТВА ВОДЫ В БЕЛЯНЫХ

В статье обсуждены результаты исследований чистоты вод реки Вислы, основанных на показаниях автоматической установки для измерения качества воды в Белянах. Исследования, проведенные в 1973 г., охватили 19 параметров загрязнения. Нценка уровня чистоты воды в Висле произведена на основе достоверных и типичных концентраций и зарядов загрязнений, а также кривых обеспеченности. Определены также показатели загрязнений на территории бассейна реки, замкнутой профилем в Белянах.

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