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HENRYK MAŃCZAK*, HALINA SZYMAŃSKA*

DETERMINATION OF THE SHAPE OF OXYGEN CURVE BASED ON PERIODICAL ANALYSIS OF WATER QUALITY

A more profound recognition of the phenomena of self-purification and the relation between DO concentration and river flow intensity allowed to work out the principles of DO curve determination from periodical examinations of water quality in measuring/control cross-sections. Determination of DO curve is based on the relations between oxygen concentration and river flow, which are expressed according to various types of regression equations (parabole, hyperbole, expotential and exponential curves, and others). Reliable DO concentrations determined from the quations are used to construct a hydrochemical profile presented in the fig. 11 and to classify the quality of waters. DO curve is a good complement of water classification based on other parameters of pollution, while in the case of severly polluted water it is absolutely necessary.

1. OXYGEN SAG CURVE

Oxygen sag curve is a graphical representation of self-purification processes occurring in the river waters. It is a resultant of all partial processes, i.e.: 1. processes which influence oxygen consumption and 2. processes which cause oxygen intake. The first group comprises the following processes: dilution of river water with inflow water of a better quality, mixing, and turbulence as well as sedimentation of suspended solids, adsorption, and mineralization of organic compounds. The second group involves processes in which oxygen is uptaken from free water surface being in contact with the atmosphere and by water aeration during its flow through overflow crest weirs, river bars, stages of fall and other hydrotechnical constructions. This group involves also the processes which cause intake of oxygen reserve coming from the up-stream and numerous tributaries as well as resulting from photosynthesis. Oxygen sag curve, called also dissolved oxygen or DO curve, is thus a result of the process of oxygen intake from the atmosphere and oxygen consumption occurring simultaneously in receivers.

* Research Institute for Environmental Development (IKŚ), Rosenbergów 28, 51-616 Wrocław Poland.

An average DO curve of polluted water has 3 characteristic points, i.e.: initial, critical, and inflection points as well as 4 subsequent self-purification zones, i.e.: exhaustion, decomposition, recovery, and clear water zones [3]. The shape of such an oxygen curve is presented in fig. 1. At the critical point, the water is characterized by the lowest rate of dissolved oxygen. The distance between the critical point and the initial point is different.

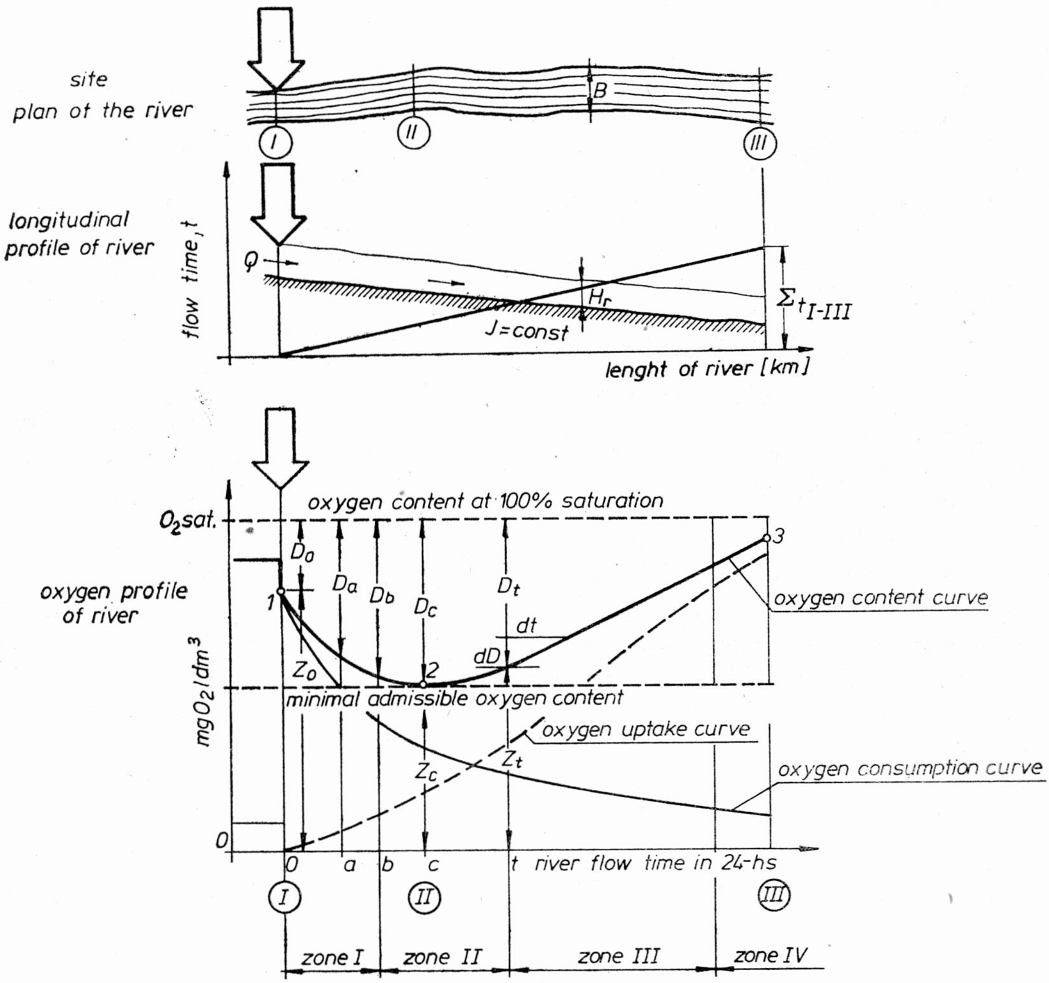

Fig. 1. Elements of oxygen sag curve in the free-flowing river

Rys. 1. Elementy warunków tlenowych w rzece naturalnej

Exhaustion zone I begins directly below sewage inflow, i.e. at the initial point. Oxygen intake processes lag behind those of oxygen consumption, and DO content decreases.

Decomposition zone II occurs distinctly in strongly polluted rivers. DO content decreases to a 40% of saturation or lower. The critical point, characterized by the lowest content of dissolved oxygen, occurs in this zone.

Recovery zone III (or zone of improvement) is characterized by phenomena opposite to those occurring in the zone of exhaustion. Oxygen consumption processes are less intensive. Intake of atmospheric oxygen prevails over its consumption, hence DO concentration increases.

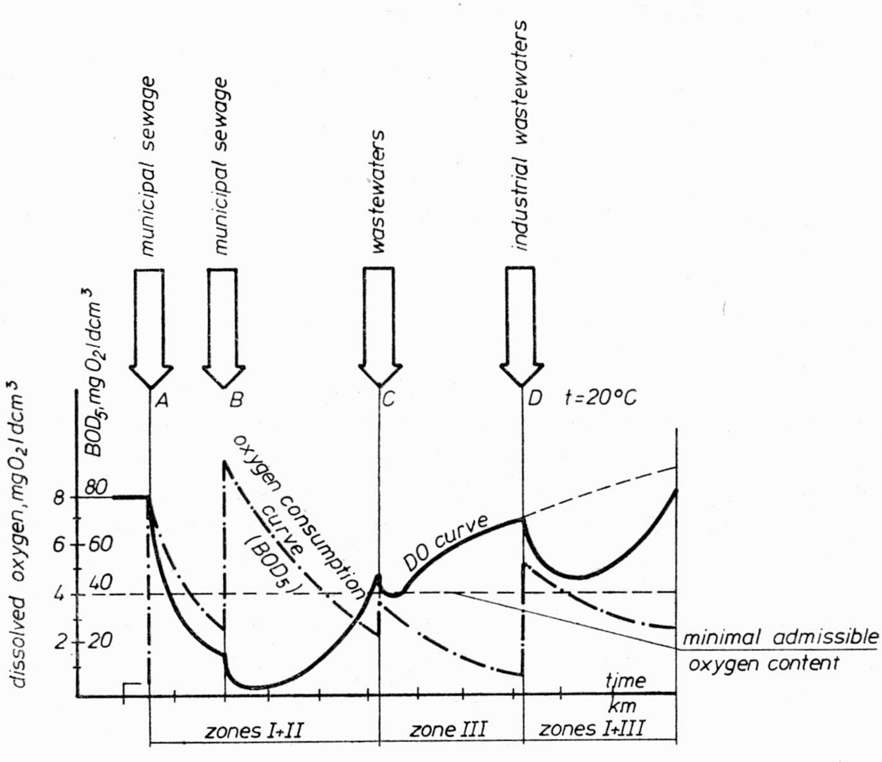

Fig. 2. Example of a wrong distribution of pollution sources in the view of oxygen conditions

Rys. 2. Przykład niewłaściwego rozmieszczenia źródeł zanieczyszczeń z uwagi na warunki tlenowe

Clear water zone IV is characterized by the normal development of water organisms. The inflection point of oxygen is found in this zone.

The shape of DO curve may be used as a basis in planning the distribution of pollution sources. If permissible pollution load coming from the initial source brought about the phenomena typical of zones I and II (fig. 2), and the critical point did not exceed the minimum permissible oxygen content in water no further pollution within zones I and II would be allowed. Additional introduction of pollution load would decrease DO to zero and cause anaerobic conditions. Thus, sitting of new plants in area within zones I and II is not allowed and if such a plant exists, its wastewater should be drained away by collecting pipe to the site below, and then treated and discharged into the river, but within the recovery or clear water zones. Another solution of that problem is a maximal purification of wastewater from the first source, which would allow to introduce a small pollution load into zones I and II [2].

The oxygen-curve shape typical of free-flowing rivers, where the processes of suspension, sedimentation and photosynthesis do not take place, may be described by equation (1):

$$D_b = \frac{k_1}{k_2-k_1} L_a(10^{-k_1 t}-10^{-k_2 t})+D_a 10^{-k_2 t}, \tag{1}$$

where:

k_1 — coefficient of biochemical oxygen consumption rate (24 h^{-1}),

k_2 — atmospheric oxygen intake coefficient (which may be calculated from the shape of oxygen curve determinated statically as hydrochemical profile), (24 h^{-1}),

t — time of water flow through the segment a–b (24 h),

D_b — oxygen deficiency in the final cross-section b (mg O_2/dm^3),

D_a — oxygen deficiency in the initial cross-section a (mg O_2/dm^3),

L_a — biochemical oxygen demand in the initial cross-section (mg O_2/dm^3).

Oxygen conditions in the polluted flow-controlled rivers are different from those in the free-flowing rivers. Impounding due to the construction of stage of fall changes hydraulic conditions of the river bed which, in turn, determine partial components of self-purification process. The reduced flow rate brings about sedimentation of suspended solids and formation of bottom sediments subject to anaerobic degradation which, finally, is responsible for the additional consumption of oxygen dissolved in water. Owing to the increasing mean depth of the river bed and decreasing flow rate, the rate of atmospheric oxygen intake decreases (fig. 3). The increase of water flow time brings about the increase of total oxygen consumption, consequently, the critical point of oxygen curve drops and shifts directly over the weir. Oxygen deficit equation may be presented as follows:

$$D_b = \frac{k_1}{k_2-k_1-k_3}\left(L_a - \frac{p}{2.3(k_1+k_3)}\right)(10^{-(k_1+k_3)t}-10^{-k_2 t}) + \frac{k_1}{k_2}\left(\frac{p}{2.3(k_1+k_3)} - \frac{a}{2.3k_1}\right)(1-10^{-k_2 t})+D_a 10^{-k_2 t}, \tag{2}$$

where:

a — DO from photosynthesis (mg $O_2/dm^3/24$ h),

k_3 — coefficient of the decrease of oxygen consumption rate due to sedimentation of suspended matter (24 h^{-1}),

p — oxygen amount consumed by bottom sediments (mg $O_2/dm^3/d$), the remaining notations being the same as in the equation (1).

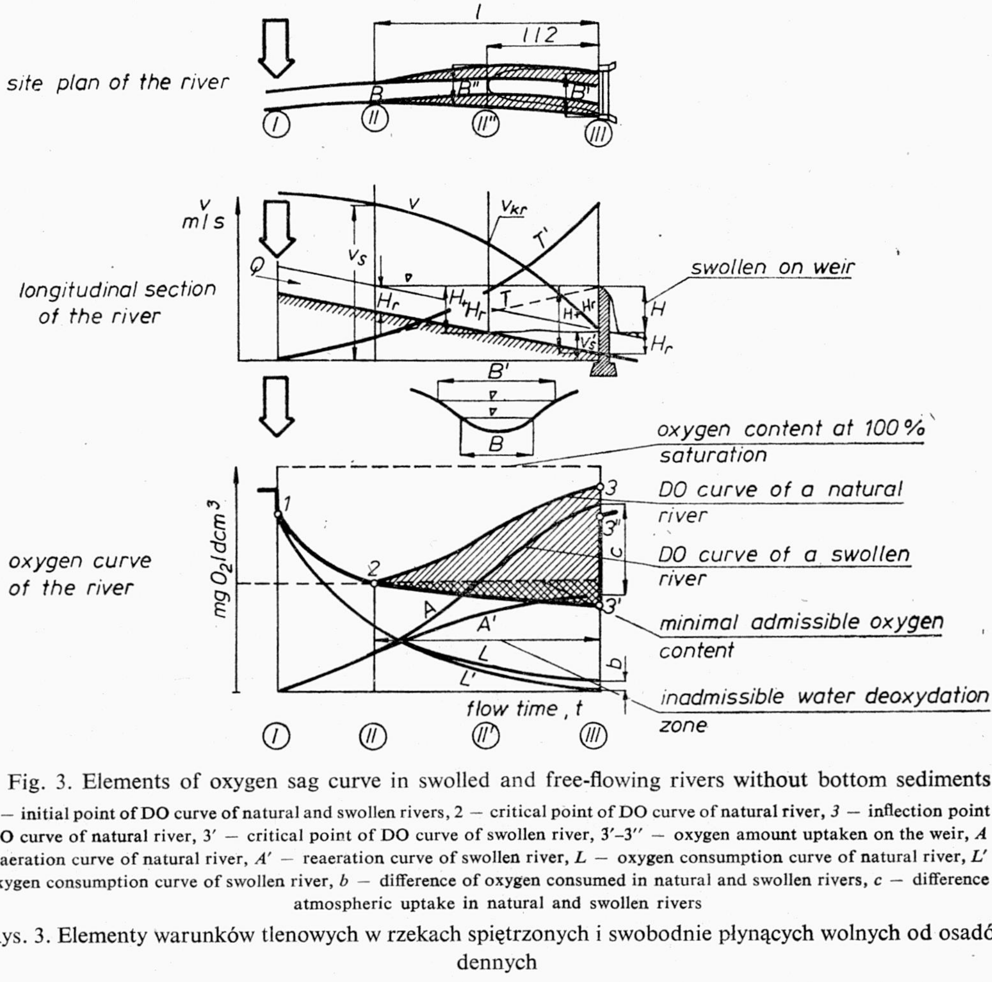

Fig. 3. Elements of oxygen sag curve in swolled and free-flowing rivers without bottom sediments

1 — initial point of DO curve of natural and swollen rivers, *2* — critical point of DO curve of natural river, *3* — inflection point of DO curve of natural river, 3′ — critical point of DO curve of swollen river, 3′–3″ — oxygen amount uptaken on the weir, *A* — reaeration curve of natural river, *A′* — reaeration curve of swollen river, *L* — oxygen consumption curve of natural river, *L′* — oxygen consumption curve of swollen river, *b* — difference of oxygen consumed in natural and swollen rivers, *c* — difference of atmospheric uptake in natural and swollen rivers

Rys. 3. Elementy warunków tlenowych w rzekach spiętrzonych i swobodnie płynących wolnych od osadów dennych

1 — punkt początkowy linii tlenowej rzeki swobodnie płynącej i rzeki spiętrzonej, *2* — punkt krytyczny linii tlenowej rzeki swobodnie płynącej, *3* — punkt przegięcia linii tlenowej rzeki swobodnie pynącej, 3′ — punkt krytyczny linii tlenowej rzeki spiętrzonej, 3′–3″ — ilość tlenu pobrana na jazie, *A* — krzywa pobierania tlenu z atmosfery rzeki swobodnie płynącej, *A′* — krzywa pobierania tlenu z atmosfery rzeki spiętrzonej, *L* — krzywa zużycia tlenu rzeki swobodnie płynącej, *L′* — krzywa zużycia tlenu rzeki spiętrzonej, *b* — różnica zużytego tlenu w rzece swobodnie płynącej i spiętrzonej, *c* — różnica pobranego tlenu z atmosfery w rzece swobodnie płynącej i spiętrzonej

Oxygen conditions of the inpounded river may be further deteriorated in the case of a water power plant with turbines built at the stage of fall. Cavitation results in oxygen depletion in river water and reduction of oxygen content at the critical point. The described condition may be even further deteriorated when below the plant there is the next stage of fall in which reaeration conditions become worsened due to swelling of water (fig. 4). As the example of negative and positive influences of water plants upon oxygen conditions in water may serve weirs. The negative influence consists in the fact that the weir swelling the water deteriorates simultaneously hydraulic conditions of the river bed and dec-

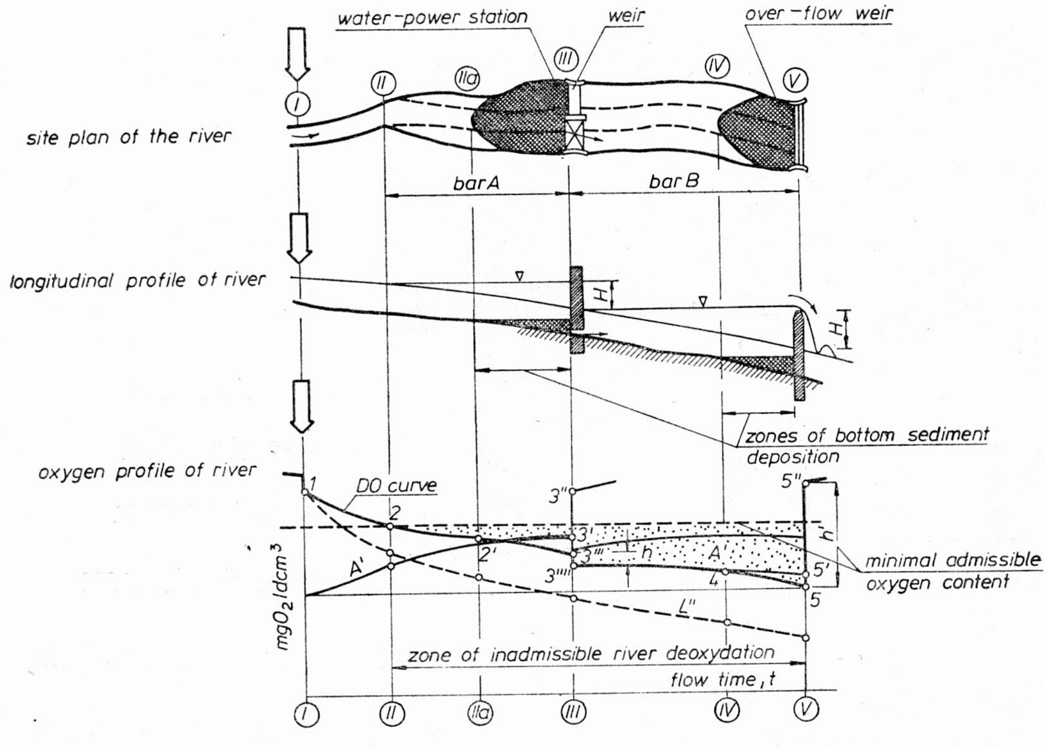

Fig. 4. Elements of oxygen sag curve in flood-control rivers used for hydroenergic purposes

1 — initial point of DO curve of natural and swollen rivers, 2 — critical point of DO curve of natural river, 2′ — oxygen content in a swollen river at the beginning of zone at which bottom sediments are deposited in the bar A, 3′ — critical point of DO curve of swollen river not affected by bottom seximents, 3″ — oxygen content below the weir of swollen river loaded with bottom sediments, 3‴ — critical point of DO curve of swollen river loaded with bottom sediments, 3⁗ — oxygen content in a swollen river below a water-power plant, *4* — dissolved oxygen content of swollen river at the beginning of zone at which bottom sediments are deposited in the bar B, *5* — critical point of swollen river loaded with bottom sediments and at the water flowing through turbines of water-power station, *5′* — critical point of swollen river not loaded with bottom sediments and at the water flowing through turbines, *5″* — oxygen content below the weir of the bar B, *h* — oxygen loss due to the water flow through the turbines of the bar A, *h′* — amount of the oxygen uptaken on the weir of the bar B, *A′* — reaeration curve of swollen river, *L″* — curve of oxygen consumption of swollen river affected by sedimentation and degradation of bottom sediments

Rys. 4. Elementy warunków tlenowych w rzece skanalizowanej wykorzystywanej hydroenergetycznie

1 — punkt początkowy linii tlenowej rzeki swobodnie płynącej i rzeki spiętrzonej, *2* — punkt krytyczny linii tlenowej rzeki swobodnie płynącej, *2′* — zawartość tlenu rzeki spiętrzonej na początku strefy zalegania osadów dennych w stopniu A, 3′ — punkt krytyczny linii tlenowej rzeki spiętrzonej bez wpływu osadów dennych, 3″ — zawartość tlenu poniżej jazu rzeki spiętrzonej obciążonej osadami dennymi, 3‴ — punkt krytyczny linii tlenowej rzeki spiętrzonej obciążonej osadami dennymi, *3⁗* — zawartość tlenu w rzece spiętrzonej poniżej zakładu hydroenergetycznego, *4* — zawartość rozpuszczonego tlenu rzeki spiętrzonej na początku strefy zalegania osadów dennych w stopniu B, *5* — punkt krytyczny rzeki spiętrzonej z wpływem osadów dennych oraz przy przepływie wody przez turbiny hydroelektrowni, *5′* — punkt krytyczny w rzece spiętrzonej bez wpływu osadów dennych oraz przy przepływie wody przez turbiny, *5″* — zawartość tlenu poniżej jazu stopnia B, *h* — tlen stracony na skutek przepływu wody przez turbiny stopnia A, *h′* — ilość tlenu pobrana na jazie stopnia B, *A′* — krzywa pobierania tlenu z atmosfery w rzece spiętrzonej, *L″* — krzywa zużycia tlenu rzeki spiętrzonej z wpływem sedymentacji i rozkładu osadów dennych reases the intensity of atmospheric oxygen intake. The positive effect, i.e. an intense intake of oxygen from the atmosphere, is due to water overfalling the crests of stationary weirs or mobile weirs. The shape of DO curve depends also on cooling water discharges into the receiver (e. g. from thermal-electric power station) as they are poore of oxygen and raise additionally water temperature in the receiver. These waters are the factor lowering the dissolved oxygen concentration due to merely physical processes in the river.

DO equation due to MAŃCZAK and KRASNODĘBSKI has somewhat different form [4]:

$$\frac{dC}{dt} + \left(a'L^{b'} + \frac{d\ln Q}{dt}\right) C = C\,\frac{d\ln Q}{dt}, \tag{3}$$

where:

C — dissolved oxygen content in the river (mg O_2/dm^3),
dQ — change of river water flow intensity (m^3/s),
dC — change of oxygen content in the river (mg O_2/dm^3).

2. RELATIONSHIPS BETWEEN DISSOLVED OXYGEN CONTENT AND THE WATER FLOW

Reliable contents of oxygen dissolved in river are determined from the relation between the mentioned index rate and water flow intensity.

Correlation between dissolved oxygen concentration and water flow depends on the degree of river pollution with organics, water temperature, the development of algae and aquatic flora as well as on hydraulic parameters of the river bed, i. e. on mean depth of river bed and the water flow rate. The relation between DO and water flow may be described by the following regression equations:

$$y = \frac{a}{x} + b, \tag{4}$$

$$y = \frac{x}{ax+b}, \tag{5}$$

$$y = \frac{a}{x+b} + c, \tag{6}$$

$$y = \frac{1}{ax+b}, \tag{7}$$

where:

y — DO concentration (mg O_2/dm^3),
x — water flow (m^3/s),
a, b, and c — constants.

For heavily polluted rivers characterized by disadvantageous water aeration conditions this relation is expressed by the curve *a* in fig. 5 [6].

For moderately and heavily polluted rivers, although characterized by favourable aeration conditions, this relation is described by the curve *b* in fig. 5 [6].

For unpolluted rivers it is represented by the curve *c* in the same figure.

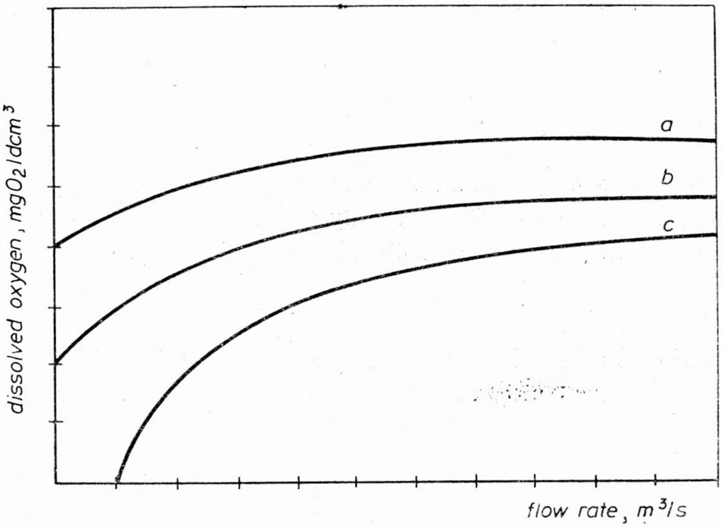

Fig. 5. Generalized relationship between DO concentration and river flow in severly polluted rivers with low and high reaeration abilities and in clean rivers

a — for unpolluted rivers, *b* — for polluted rivers with high reaeration capacity, *c* — for polluted rivers with low reaeration

Rys. 5. Uogólniony związek między zawartością rozpuszczonego tlenu i przepływem w rzekach silnie zanieczyszczonych z małą i dużą zdolnością reaeracji oraz w rzekach czystych

a — dla rzek czystych, *b* — dla rzek zanieczyszczonych z dużą reaeracją, *c* — dla rzek zanieczyszczonych z małą reaeracją

The above-generalized dependences may be confirmed by the relations presented in fig. 6. They concern the cross-sections of the town of Racibórz at severily polluted the Odra river, the cross-section localized below the weir on the Odra river in Opole (within the segment of moderate pollution), and the cross-section of the estuary of the clear Bóbr river. All those relations are based on the results of study made in 1973 [7].

3. THE PRINCIPLES OF DETERMINATION OF OXYGEN CURVE EXEMPLIFIED BY THE ODRA RIVER

The shape of the river DO curve has been established from the results of examination made by four voivodeship services of the environment protection in 1973. 51 measuring control cross-sections were distributed along the whole length of the Odra river starting

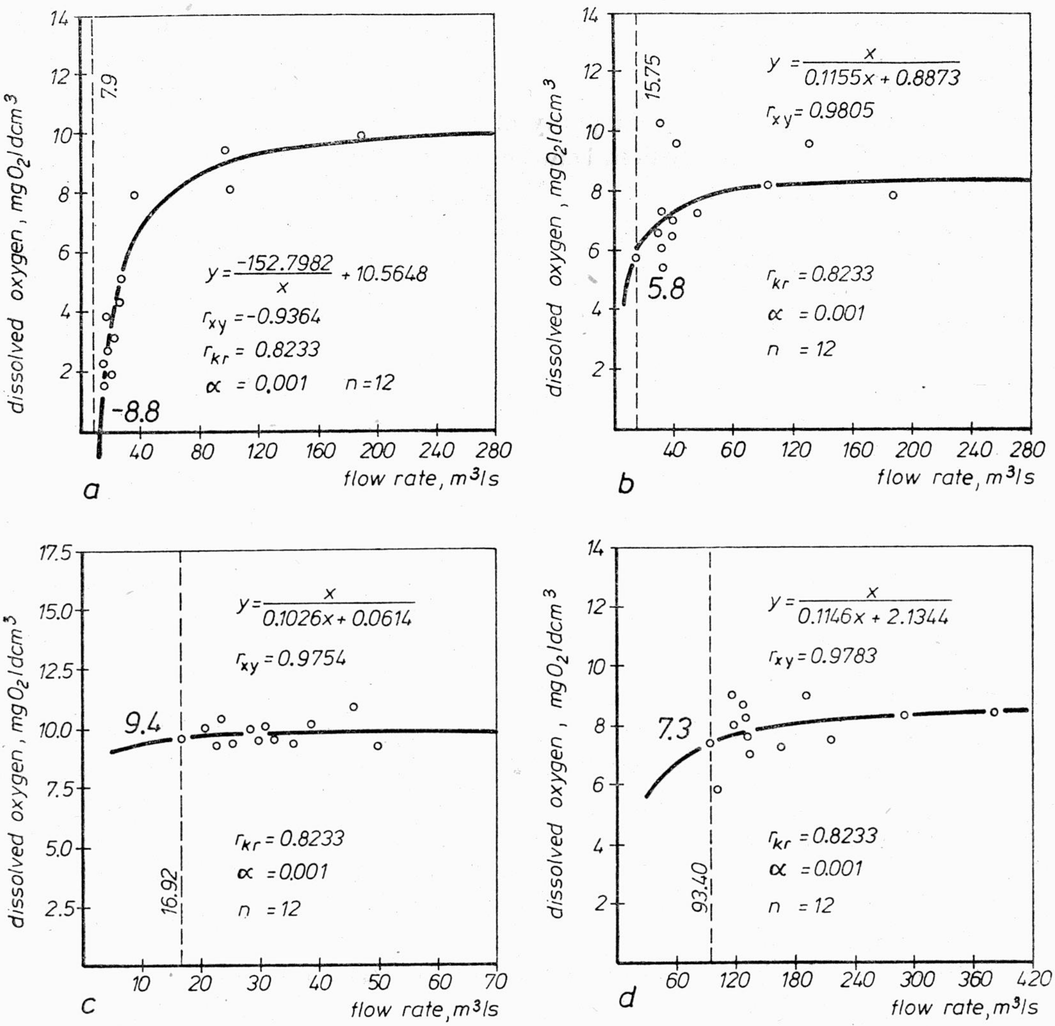

Fig. 6. Relationships between DO concentration and the Odra river flow for 1973

a — at the cross-section of the town of Racibórz, *b* — at the cross-section below the weir in Opole, *c* — at the cross-section of the river Bóbr mouth, *d* — at the cross-section below the river Bóbr mouth

Rys. 6. Związki między zawartością tlenu rozpuszczonego i przepływem rzeki Odry dla roku 1973

a — w przekroju miasta Raciborza, *b* — w przekroju poniżej jazu w Opolu, *c* — w przekroju ujściowym rzeki Bóbr, *d* — w przekroju poniżej ujścia Bobru

from the cross-section at the Czechoslovakian frontier to the cross-section localized at the estuary in the region of Szczecin bay. Water samples taken once a month from the fixed cross-section were used to determine the temperature and dissolved oxygen concentrations. The intensities of instantaneous flows in the respective cross-sections of the river have been determined by the Institute of Meteorology and Water Management in Wrocław. Reliable flow (SNQ), i. e. the mean low flow of several years, refers to the period 1960–1970. Hydrochemical profile has been constructed by marking on the X-axis the separate segments (in km) of the river, pollution sources, tributaries, and most important hydrotechnical constructions affecting the purity of river water as well as measuring control cross-sections for which the relations between the river flow intensity and dissolved oxygen concentration have been determined. The determined reliable dissolved oxygen concentrations and the water temperature values for all the measuring control cross-sections localized on the Odra river and in the estuaries of 11 controlled tributaries of the main river have been placed on the Y-axis. Allowable concentrations of dissolved oxygen for three classes of water quality have been marked on the profile. The profile included also the reliable flow curve.

The reliable concentration of dissolved oxygen and the reliable value of oxygen saturation have been determined by MAŃCZAK method [5]. To establish the mentioned relation two types of regression equations have been used:

$$y = \frac{a}{x} + b \quad \text{and} \quad y = \frac{x}{ax+b}.$$

The choice of the curve, consisting in determining the significance level of the correlation between the flow and the concentration of the pollutant given, is made by comparing the correlation coefficients, i. e. calculated r_{xy} and critical r_{cr}, at the same time veryfying (at the established significance level α) the statistical hypothesis that the latter one is significantly different from zero. We have assumed after CRAMER that the deviation of the mentioned coefficient is: almost significant at $\alpha = 0.1$, significant at $\alpha = 0.01$, and very significant at $\alpha = 0.001$ [5]. We may assume $\alpha = 0.2$ for biodegradable pollutants and $\alpha = 0.1$ for the remaining ones, when the deviation of correlation coefficient is almost significant.

The DO curves have been based on the respective connections of the reliable values of dissolved oxygen concentrations.

Oxygen concentration drops in cross-sections of sewage discharges and inlets of tributaries more polluted than the main river. This decrease is due to the immediate oxygen demand by wastewaters inflowing the main river and by its tributaries the water of which are less oxygen-saturated than that of the main river. The determination method of dissolved oxygen concentration below the source of pollution is presented in fig. 7. Oxygen concentration in the cross-section above the pollution source is obtained from analyses, whereas that below the source is established by DO curve extrapolation. The DO curve had been determined by analysis of water samples taken from the cross-sections localized below the effluents of wastewaters [3]. If the oxygen saturation of tributary water is lower than that of the main river, the DO concentration below this tributary is determined in the way shown in fig. 8 and calculated according to the equation:

$$O_{2b} = \frac{O_{2a}Q_a + O_{2c}Q_c}{Q_a + Q_c}, \tag{8}$$

where:

O_{2b}, O_{2a} – DO concentrations below and above tributary, respectively (mg O_2/dm^3),
O_{2c} – DO content in the inflowing river (mg O_2/dm^3),
Q_a, Q_c – main and tributary flow rates, respectively (m^3/s).

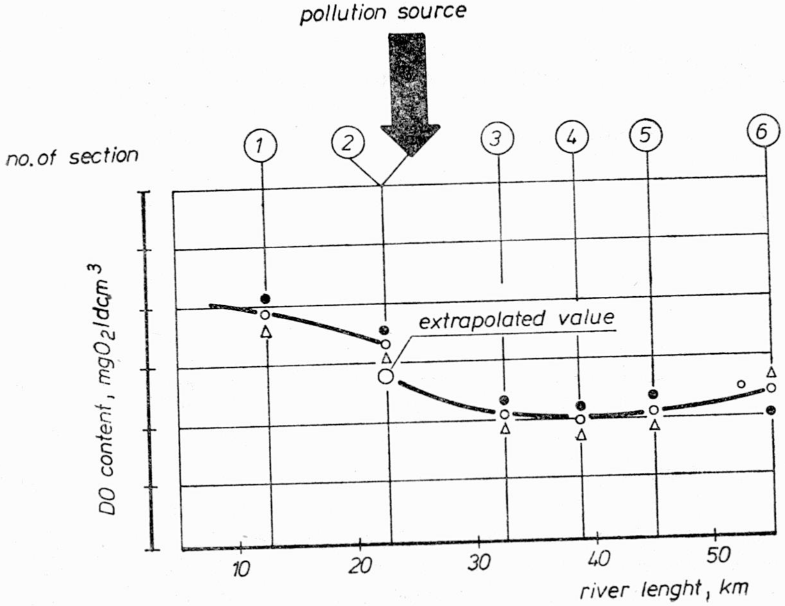

Fig. 7. The method of DO concentration determination in the main river water below the pollution source

● – left bank, ○ – current, △ – right bank

Rys. 7. Sposób wyznaczania zawartości tlenu rozpuszczonego w wodzie rzeki głównej poniżej źródła zanieczyszczenia

● – brzeg lewy, ○ – nurt, △ – brzeg prawy

DO concentrations in the main river water increase in cross-sections of tributaries (where the water is more clean than in the main river) and in the cross-sections of such hydrotechnic constructions as mobile and stationary weirs. If water of tributaries are more saturated with oxygen than that of the main river, DO concentration in the latter below the tributary is determined in the way shown in fig. 9 and calculated according to the equation (8).

Fig. 10 shows the way of determining the DO curve for the main river within mobile and stationary weirs [3]. In this case the increase in oxygen concentration is chiefly due to atmospheric oxygen intake during the water flow through the crest weir. The changes in temperature and DO content in the Odra river are shown in fig. 11. The values of water temperature in measuring cross-sections marked in the profile are arithmetic means from 12 results obtained during one year.

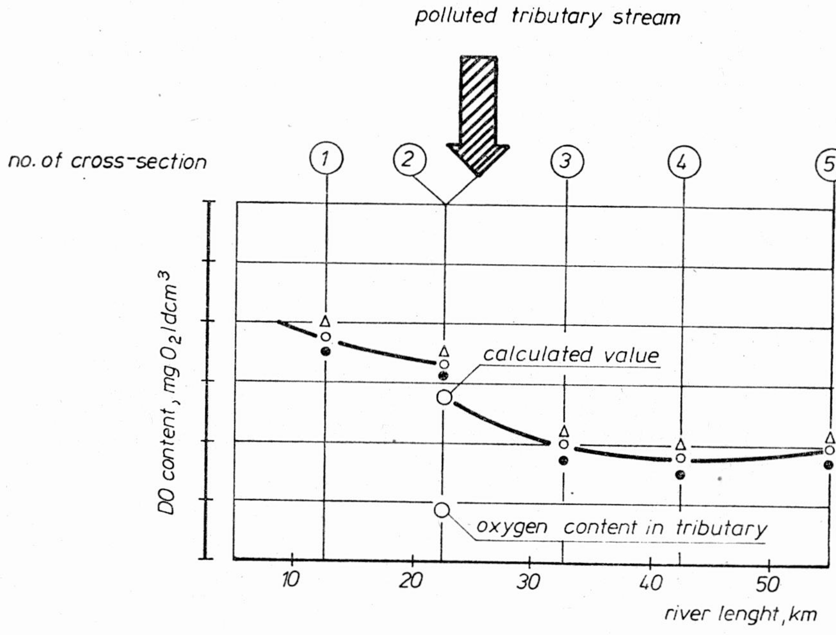

Fig. 8. The method of DO concentration determination in the main river water below the river supply with polluted and deoxidated water

● — left bank, ○ — current, △ — right bank

Rys. 8. Sposób wyznaczania zawartości tlenu rozpuszczonego w wodzie rzeki głównej poniżej dopływu prowadzącego wodę zanieczyszczoną i odtlenioną

● — brzeg lewy, ○ — nurt, △ — brzeg prawy

4. WATER QUALITY CLASSIFICATION BASED ON THE SHAPE OF DO CURVE

From the analysis of changes in reliable DO concentrations in the river Odra it follows that unacceptable deoxidation of its water took place in 1973 along the segments whose total length covered 26.4% of the controlled river flow. 8.2% of the river were represented by water of III quality class, whereas 22.5% — by water of II class. The cleanest water of the DO concentration exceeding 6 mg O_2/dm^3 (I class) was stated along the total length of 42.9%. That kind of water is mainly during lower river flows.

5. SUMMARY

Relations between DO concentration and river flow constitute the basis for determining the DO curve from the results of periodical examinations in measuring/control cross-sections.

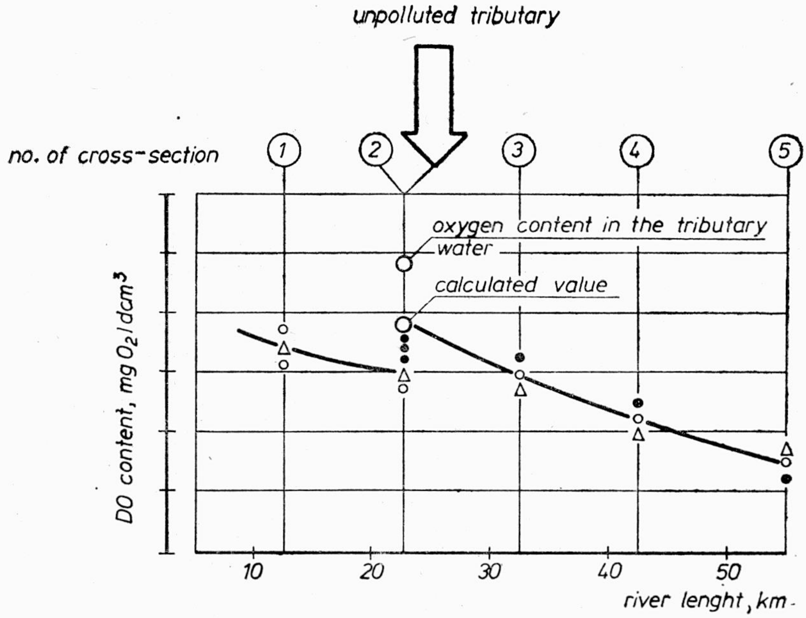

Fig. 9. The method of DO concentration determination in the main river water below the river supply with clean water

● — left bank, ○ — current, △ — right bank

Rys. 9. Sposób wyznaczania zawartości tlenu rozpuszczonego w wodzie rzeki głównej poniżej dopływu wody czystej

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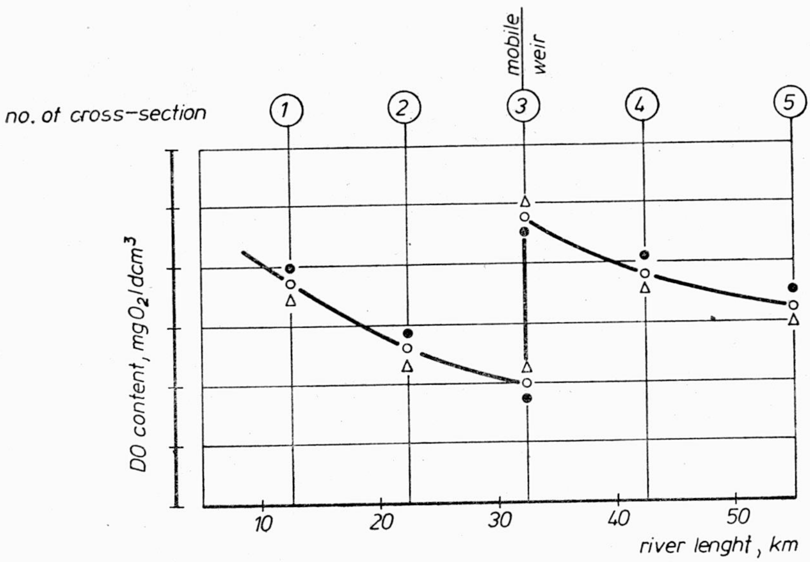

Fig. 10. The method of DO concentration determination in the main river water within the mobile weirs

● — left bank, ○ — current, △ — right bank

Rys. 10. Sposób wyznaczania zawartości tlenu rozpuszczonego w wodzie rzeki głównej w obrębie jazów ruchomych

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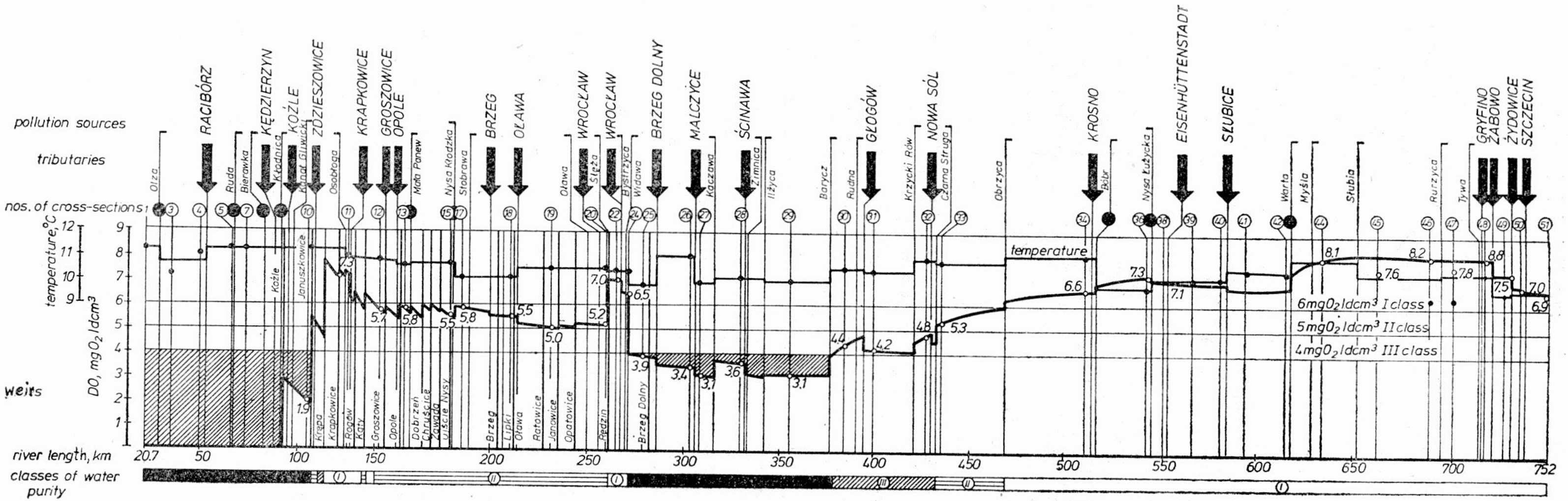

Fig. 11. DO curve of the Odra river in 1973

Rys. 11. Linia tlenowa Odry dla roku 1973

The mentioned relationships expressed graphically take different shapes (parabole hyperbole, expotential and exponential curves, and others) which depend on the degree of river water pollution with oxygen-consuming organics, hydraulic parameters of the river bed which affect aeration and on the temperature of water. In cross-sections of wastewater discharge and outlets of tributaries, where these relations cannot be determined because of mixing, the ordinates of DO curve are calculated from the equation of oxygen loads.

The accuracy of calculations of the reliable DO concentration from the relation between flow and the value of this parameter depends on the number of results obtained. From other works it follows that 50 results obtained in a year approximate the phenomenon discussed with a sufficient accuracy.

DO curve determined from the results of periodical examination is an additional complementary factor in water classification, and in the case of severly polluted water is absolutely necessary.

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ZASADY WYZNACZANIA KSZTAŁTU LINII TLENOWEJ RZEK NA PODSTAWIE PERIODYCZNYCH BADAŃ JAKOŚCI WODY

Lepsze poznanie zarówno samooczyszczania się wód, jak i zależności między zawartością tlenu rozpuszczonego a natężeniem przepływu rzeki pozwoliło na opracowanie zasad wyznaczania kształtu linii tlenowej wód płynących. Wyznaczenia tego dokonano badając periodycznie jakość wody w przekrojach pomiarowo-kontrolnych. Linie tlenowe wyznaczono z zależności między zawartością tlenu a przepływem rzeki. Zależności te układają się według różnych typów równań regresji (parabola, hiperbola, krzywa wykładnicza, potęgowa i inne), a wyznaczone z nich miarodajne zawartości rozpuszczonego tlenu służą do konstrukcji profilu hydrochemicznego (rys. 11) i klasyfikacji jakości wód. Linia tlenowa stanowi dobre uzupełnienie klasyfikacji wód przeprowadzonej na podstawie innych wskaźników zanieczyszczenia, a w przypadku wód silnie zanieczyszczonych jest absolutnie konieczna.

GRUNDLAGEN ZUR BESTIMMUNG DER SAUERSTOFFLINIE IN FLÜSSEN ANHAND VON PERIODISCHEN WASSERUNTERSUCHUNGEN

Bessere Erkenntnisse von Selbstreinigungsvorgängen in den Fließgewässern, wie auch der Verhältnisse zwischen dem Sauerstoffgehalt und der Durchflußmenge gestatten die Aufstellung von Richtlinien zur Aufzeichnung der Sauerstoffkurve. Zeitgemäße Wasseruntersuchungen müssen in festgelegten Meßquerschnitten durchgeführt werden. Die Sauerstofflinien werden aus den Verhältnissen zwischen dem Sauerstoffgehalt und der Durchflußmenge aufgezeichnet. Verschiedene Regressionsformeln können aufgestellt werden (Parabel, Hyperbel, Exponentialkurve, Potenzlinie u. a.). Die errechneten Sauerstoffkonzentrationen werden bei der Aufstellung der hydrochemischen Profile (Abb. 11) und zur Klassifizierung der Wassergüte ausgenutzt. Die Sauerstofflinie ist eine gute Ergänzung der erwähnten Klassifizierung die Anhand von markanten Verschmutzungsfaktoren formuliert wird; bei stark verschmutzten Gewässer ist sie unentbehrlich.

ПРИНЦИПЫ ОПРЕДЕЛЕНИЯ ФОРМЫ КИСЛОРОДНОЙ ЛИНИИ РЕК НА ОСНОВЕ ПЕРИОДИЧЕСКИХ ИССЛЕДОВАНИЙ КАЧЕСТВА ВОДЫ

Лучшее познание как самоочистки вод, так и зависимости между содержанием растворённого кислорода и расходом реки позволило разработать принципы формы кислородной линии текущих вод. Это определение было произведено при периодическом исследовании качества воды в измерительно-контрольных створах. Кислородные линии определены в зависимости между содержанием кислорода и расходом реки. Эти зависимости укладываются по различным типам уравнения регрессии (парабола, гипербола, экспоненциальная, степенная и другие кривые), а определённые на их основе достоверные содержания растворённого кислорода служат для конструкции гидрохимического профиля (рис. 11) и классификации качества вод. Кислородная линия представляет собой пополнение классификации вод, проведённой на основе других показателей загрязнения, а в случае сильно загрязнённых вод является абсолютно необходимой.