ECOLOGICAL CHEMISTRY AND ENGINEERING A

Vol. 18, No. 2 2011

Tadeusz MOLENDA[1] and Damian CHMURA[2]

SEASONAL CHANGES IN SELECTED PHYSICOCHEMICAL PARAMETERES OF SALINE WATER BODIES (CASE STUDY OF RETENTION-DOSING RESERVOIR "BRZESZCZE")

SEZONOWE ZMIANY WYBRANYCH PARAMETRÓW FIZYKOCHEMICZNYCH SŁONYCH ZBIORNIKÓW WODNYCH (NA PRZYKŁADZIE ZBIORNIKA RETENCYJNO-DOZUJĄCEGO „BRZESZCZE")

Abstract: The paper presents results of physicochemical parameters (temperature, pH, conductivity, salinity, oxygenation, oxydation reaction potential, turbidity) in man-made water body.

The conducted studies indicated that anthropogenic saline reservoirs are typified by specific limnic processes. It concern especially myctic processes, which are distinctly different from those known from fresh water lakes. The "Brzeszcze" reservoir is of bradymictic type, characterized by advantage of stagnation over mixing. Differences in conductivity between bottom and surface waters within 3 meters varied from 5.4 $mS \cdot cm^{-1}$ to 11.8 $mS \cdot cm^{-1}$. The waters were also characterized by large decrease in oxygenation with depth and between seasons from more than 22 to ca 1 mg O_2/dm^3. The hydrological situation in "Brzeszcze" is to the some extent similar an estuary. The movement of waters is determined by the process called "anthropomixing". Another unusual feature was high short-term changes within 5 minutes in conductivity and turbidity probably associated with waving caused by wind.

Keywords: limnic processes, saline waters, anthropogenic water bodies, halophytes

Coal mine activity causes many negative consequences in natural environment. One of the most serious problems is output of coal mine saline waters. According to hydrological dictionary [1] mining waters are both waters flowing to pits from drainaged orogen and technological waters introduced with hydraulic stowage. In the area of Upper Silesian Coal Mine Industry majority of mine waters is characterized by high degree of salinity. According to qualitative classification there are four groups of

[1] Chair of Physical Geography, University of Silesia, ul. Będzińska 60, 41–200 Sosnowiec, Poland, email: tedimolenda@interia.pl

[2] Institute of Engineering and Environmental Protection, Faculty of Materials and Environmental Sciences, Universty of Bielsko-Biala, ul. Willowa 2, 43–309 Bielsko-Biała, Poland, email: dchmura@ath.bielsko.pl

mining waters [2]. These are fresh waters (I), industrial waters (II), brackish waters (III) and salt waters. Fresh waters are those in which general content of dissolved substances is estimated at not higher than 1.0 g · dm^{-3} and concentration of chloride and sulphate ions ($Cl^- + SO_4^{2-}$) lower than 0.6 g · dm^{-3}. Mineralization of industrial waters ranges from 1.0 to 3.0 g · dm^{-3} and concentration of chloride and sulphate ions ($Cl^- + SO_4^{2-}$) varies between 0.6 to 1.8 g · dm^{-3}. Brackish waters are characterized by range of the ion concentration from 3.0 to 7.0 g · dm^{-3}. Salt waters are waters with mineralization > 70 g · dm^{-3} and concentration ($Cl^- + SO_4^{2-}$) > 42 g · dm^{-3}.

As it was mentioned before, discharge of salt waters into surface streams caused many negative consequences in fresh water ecosystems. In order to reduce the negative influence of salt waters on environment many technical solutions are applied. One of such solutions is hydrotechnical method. It consists in keeping of salt waters in retention-dosing water bodies and next their controlled discharge into surface streams. Salt water discharge is most frequently performed in the period of high waters state. Then they become strongly diluted, and negative impact on ecosystem is minimalized.

Although, retention-dosing water bodies are objects of anthropogenic origin, however, from time to time they undergo the same processes as natural lakes. It concerns also remaining man-made water reservoirs [3]. High degree of salinity of retentioned waters lead to their distinctiveness of limnic processes in comparison with typical fresh water reservoirs. Therefore, such objects are named as "halinothrophic reservoirs" – the term introduced by Molenda [3]. It concerns only chemical (trophic) traits but it does not take into account genesis of reservoirs. Other halinotrophic reservoirs may be remaining anthropogenic water bodies as subsidence or exploitation hollow reservoirs. The term "halinotrophy" is being more and more popular in hydrological papers eg Jankowski and Rzetala [4].

The main goal of this work is to verify hypothesis that chosen limnic processes (mixing) in anthropogenic salt-water reservoirs are similar to those ones in natural fresh water reservoirs. In particular, it was examined: what seasonal changes in chosen hydrochemical traits are ie between period of mixing (autumn-spring) and stagnation (winter--summer); whether there is a relationship between degree of oxygenation and content of chlorophyll; and if there is a distinct a relationship between oxygenation and pH in such objects. Finally, it was checked if the vicinity of the studied body halophytes grow.

Material and methods

Localization of the study area

According to physical-geographical division of Poland the investigated reservoir is situated in Oswiecim Valley in Brzeszcze. This water body was opened in 1979. The area of the reservoir is estimated at 27.5 ha and its capacity – 1 155 747 m^3. This object is supplied by mining waters from coal mine "Brzeszcze" – 7000 $m^3 \cdot d^{-1}$. They are characterized by low degree of salinification and were classified to III group. The reservoir water-storage capacity enables retention of mining waters apart from draining to Wisla River during 4–5 months. Discharge of salt waters to Wisla is performed by

bottom sluices of capacity 80 000 $m^3 \cdot d^{-1}$, what facilitates complete emptying of the reservoir within 14 days [5].

Methods

The measurements of selected parameters of water such as: temperature, pH, conductivity, salinity, oxygenation, oxidation reaction potential and turbidity as well as content of chlorophyll *a* were performed directly in the field using 6600 UPG Multi-Parameter Water Quality Monitor with terminal YSI 650 MDS every 0.5 of meter of depth. The measurements were collected every 5 seconds within 10 minutes. The point of profile studies were located in the deepest site in the water body close to flood-gate. Also these parameters were collected in other parts of the reservoir. Within a 5 m distance from the bank of the reservoir floristic inventory of vascular plants were done. Nomenclature of plant names follows Mirek et al [6]. The relationship between oxygenation and pH as well as oxygenation and content of chlorophyll for whole data set was examined by Spearman rank correlation using free R software (http://www.r-project.org).

Results

The conducted studies indicated that in the water body "Brzeszcze" there are high vertical gradients of selected traits of water environment. Even in autumn and spring differences in conductivity are to be found (Fig. 1).

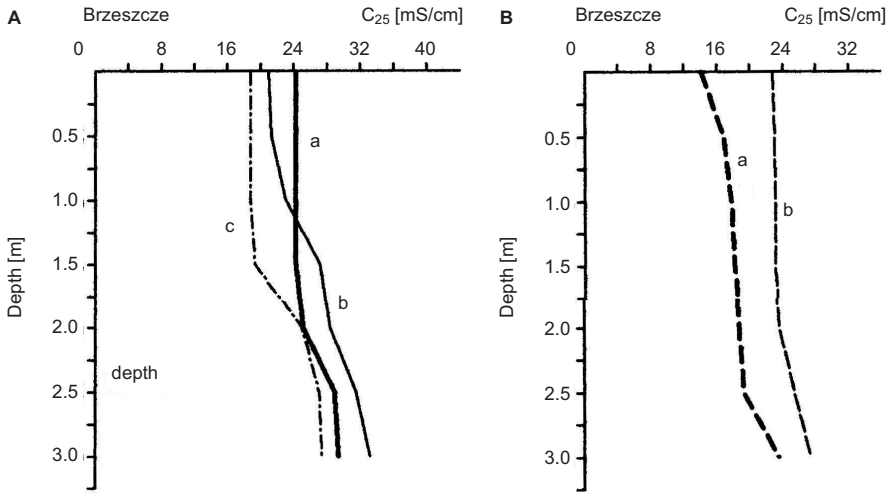

Fig. 1. Changes in conductivity of waters in vertical profile; A – autumn-spring (mixing): a – autumn 2008, b – spring 2008, c – spring 2006; B – winter-summer (stagnation): a – winter 2006, b – summer 2008

Despite that, maximal depth of reservoir during the studies amounted to 3 m (it can changes due to level of accumulation) difference in conductivity of surface and bottom waters amounted to 5.4 mS $\cdot$ cm^{-1}. Higher differences were noted in spring – 11.8

mS · cm^{-1}. Also in summer differences in conductivity between surface and bottom layer were apparent – 5.3 mS · cm^{-1}.

Also "Brzeszcze" reservoir is typified by high vertical gradients of an oxygenation from the highest ca 22 mg O_2/dm^3 to the ca 1 mg O_2/dm^3. Both in spring, summer and in autumn in surface layer high oxygenation of water is being observed (Fig. 2).

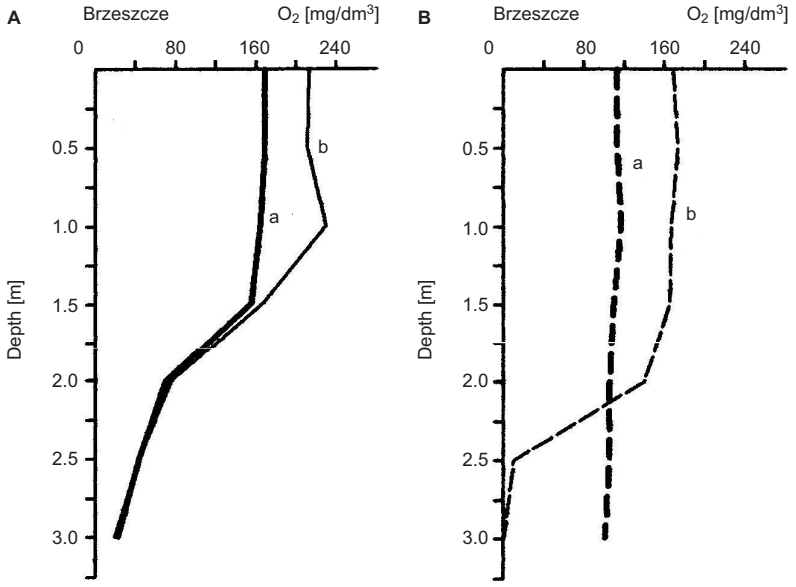

Fig. 2. Changes in oxygenation [mg O_2/dm^3] in vertical profile; A – autumn-spring: (mixing) a – autumn 2008, b – spring 2008; B – winter-summer (stagnation): a – winter 2006, b – summer 2008

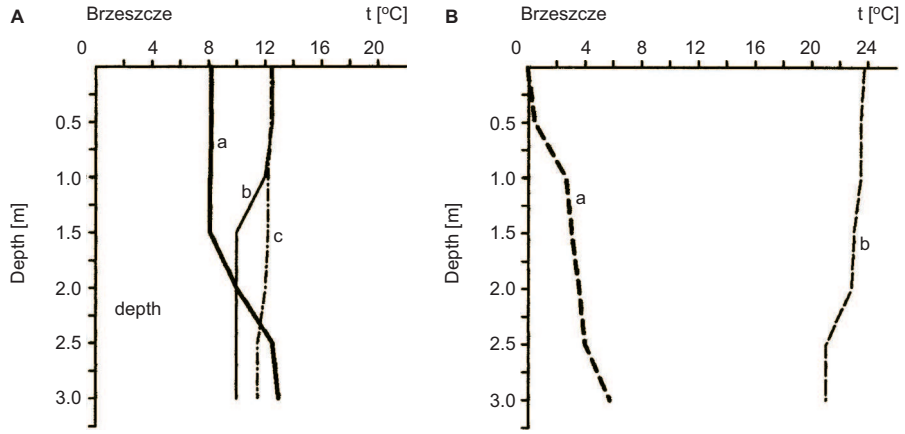

Fig. 3. Changes in temperature [°C] of waters in vertical profile; A – autumn-spring (mixing): a – autumn 2008, b – spring 2008, c – spring 2006; B – winter-summer (stagnation): a – winter 2006, b – summer 2008

Analysis of temperature of water during spring shows that it is lower and not too much differentiated and amounts to ca 12 ^{o}C in whole vertical profile (Fig. 3).

Also in remaining periods gradients of temperature are low and do not exceed 4 ^{o}C. Despite this considerable gradients in conductivity are observed.

The aforementioned oxygenation of water is also manifested by a high value of correlation coefficient between value of oxygenation [%] and pH (Fig. 4).

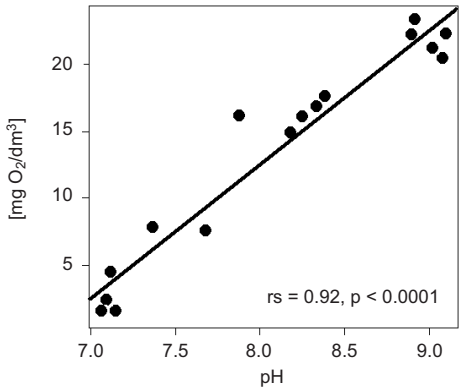

Fig. 4. Relationship between oxygenation [O_2/dm^3] and pH; data from three profile points

It is also confirmed by relationship between content of chlorophyll and value of oxygenation [%] (Fig. 5).

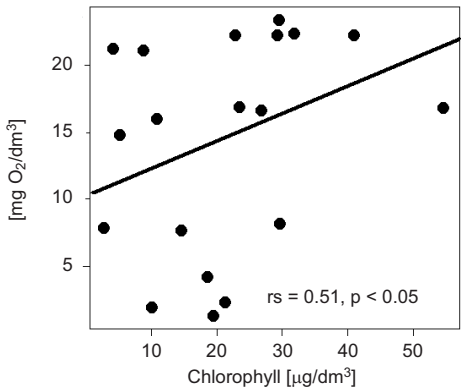

Fig. 5. Relationship between oxygenation [O_2/dm^3] and content of chlorophyll; data from three profile points

Since in surface layer saturation of oxygen in water is observed thus with increasing depth its successive decrease occurs. In bottom zone even in spring and autumn very low oxygenation of water below 2 mg O_2/dm^3 was recorded. However, in summer there are anaerobic conditions.

Apart from gradients in vertical profile in water body dynamic changes in physical parameters of surface waters were noted. When waving was moderate (height of wave 0.25 m) conductivity within 10 min varied in the range from 20.023 to 21.609 mS · cm^{-1} (Fig. 6).

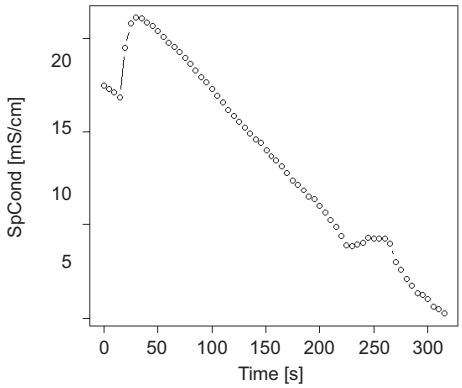

Fig. 6. Changes in conductivity of waters of Brzeszcze reservoir (online measurements every 5 seconds)

Thereby amplitude amounted to 1.585 mS · cm^{-1}. Such high dynamics was noted at the case of turbidity which varied from 26 to 87 NTU (Fig. 7).

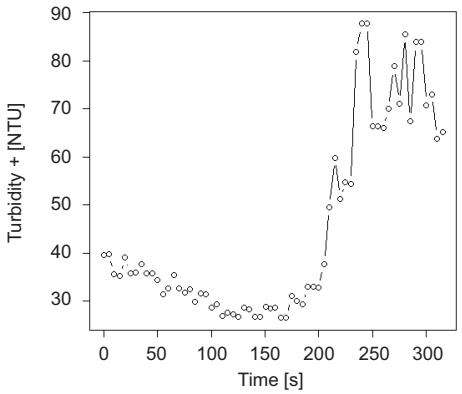

Fig. 7. Changes in turbidity of waters of Brzeszcze reservoir (online measurements every 5 seconds)

Dynamic changes of this parameter were the aftermath of resuspention of bottom sediments in littoral zone.

Discussion

Based on the studies it can be inferred that water body "Brzeszcze" is of bradymictic type, characterized by advantage of stagnation over mixing. Hampered mixing is an

aftermath of high differences in water density. Despite of this process, in this reservoir there is water circulation at the horizontal level in relation to inflow – outflow. Saline waters with higher density dropped to the bottom, whereas those ones with lower density remained in surface layer. Observed very high gradients in water mineralization are not frequently to be found in shallow reservoirs. Such reservoirs belong to group of polymictic water bodies characterized by many cycles of mixing within a year. Especially surprising are very high differences in mineralization of waters in spring and autumn. It is a period where temperature of water is constant, in which even in deep reservoirs thermal and density gradients decreased [7].

Additionally salt waters from surface layer are diluted by groundwaters and rainfall. The hydrological situation in "Brzeszcze" is to the some extent similar to an estuary. There are conditions for forming of salt-water wedge on which river fresh water are moved [8]. This reservoir is characterized by specific processes of water movement which can be determined as "anthropomixing". The examples anthropomyctic water bodies are also tanks responsible for water circulation in power plants [9].

When oxygenation of waters is concerned it should be concluded that such considerable oxygenation of water is a consequence of photosynthesis. Such relationship which is the effect of photosynthesis was revealed in numerous experimental studies [10, 11].

Taking into account seasonal changes and high vertical gradients in oxygenation similar results were obtained by Lange and Maslanka [12] in shallow lake Wierzcholek in Pomerania region. However, their observations concerned only summer. In spring and autumn there completed mixing took place and bottom waters releasing methane and sulphur hydrogen simultaneously becoming oxygenated. Also Molenda [13] reported similar oxygen conditions in shallow subsidence reservoir "Maroko" localized in Katowice. Deoxidation of bottom waters and high oxygenation of surface waters is a result of eutrophization of waters of reservoir [14]. Together with increasing depth value of redox potential changes. In surface layer always processes of oxidation take place but in bottom reduction processed were present.

Another very interesting feature of studied anthropogenic saline reservoir is very high dynamic short-term changes of physical parameters. The periodical changes within a day (in one hour intervals) in case of conductivity are known from literature [15] and can be high. In the cited study short-term changes were due to strong impact by the sea. Such changes could be result of hydrometerological conditions (state of Baltic sea, speed and direction of wind, value of runoff from the catchment). In this study changes both in conductivity and turbidity probably are associated only with wind even if its wind speed was not very high but caused waving what influenced changes in physicochemical parameters of waters.

As it was aforementioned the water body "Brzeszcze" is a salt-water reservoir. Waters of the water body affect vegetation in littoral zone. It is reflected by the occurrence of halophyte species as *Puccinellia distans* – indicator of salt waters, obligatory halophyte [16], as well as abundant in this are facultative halophytes [17] *Chenopodium glaucum, Daucus carota*, *Agrostis capillaris*, *Trifolium repens*, *Calamagrostis epigeios* and *Centaurea jacea*. There were other present species assigned the

latter group eg *Equisetum arvense*, *Potentilla anserina*, *P. reptans*, *Plantago lanceolata*, *P. major*, *Achilea millefolium* and *Taraxacum officinale*.

Conclusions

1. The conducted studies indicated that halinothrophic reservoirs are typified by specific limnic processes. It concern especially myctic processes, which are distinctly different from those known from fresh water lakes. The hydrological situation in such objects can be similar to estuaries.

2. Conductivity and turbidity seem to be very unstable parameters probably due waving caused by wind, therefore they should be analyzed with a special caution.

References

[1] Magnuszewski A. and Soczyńska U. (eds.): Międzynarodowy słownik hydrologiczny. Wyd. Nauk. PWN, Warszawa 2001.

[2] Rogoż M.: Poradnik hydrogeologa w kopalni węgla kamiennego. Wyd. Śląsk, Katowice 1987.

[3] Molenda T.: [in:] Jeziora i sztuczne zbiorniki wodne procesy przyrodnicze oraz znaczenie społeczno-gospodarcze. Uniwersytet Śląski, Sosnowiec 2005, p. 161–168.

[4] Jankowski A.T. and Rzętała M.: [in:] Natural and human environment of Poland. A geographical overview, M. Degórski (ed.), PAN, Warszawa 2006, p. 86–92.

[5] Wilk Z. (ed.): Hydrogeologia polskich złóż kopalin i problemy wodne górnictwa, t. 1. Uczelniane Wydawnictwa Naukowo-Dydaktyczne AGH, Kraków 2003, 610 p.

[6] Mirek Z., Piękoś-Mirkowa H., Zając A. and Zając M.: Flowering plants and pteridophytes of Poland a checklist. PAN, W. Szafer Institute of Botany, Kraków 2002.

[7] Choiński A.: Limnologia fizyczna Polski, Wyd. Nauk. UAM, Poznań 2008.

[8] Allen P.A.: Procesy kształtujące powierzchnię Ziemi. Wyd. Nauk. PWN, Warszawa 2000.

[9] Rzętała M.: Funkcjonowanie zbiorników wodnych oraz przebieg procesów limnicznych w warunkach zróżnicowanej antropopresji na przykładzie regionu górnośląskiego. Wyd. Uniwersytetu Śląskiego, Katowice 2008.

[10] Neverova-Dziopak E.: Ekologiczne aspekty ochrony wód powierzchniowych. Ofic. Wyd. Politechniki Rzeszowskiej, Rzeszów 2007.

[11] Tsvetkova L.I., Neverova-Dziopak E. and Usanov B.P.: [in:] Mat. 2 Mieżdunarodnaja jewroazjatska konf. "Putireszenija ekołogiczeskich problem transportnych korridorow", St. Pieterburg, Russia 2000, p. 213–224.

[12] Lange W. and Maślanka W.: Struktura tlenowa wybranych jezior Pojezierza Pomorskiego, Rocznik Fizycznogeograficzny, T. 1, Uniwersytet Gdańsk 1996.

[13] Molenda T.: Rewitalizacja ekosystemów wodnych w warunkach zróżnicowanej antropopresji (na przykładzie Ekologicznego Systemu Obszarów Chronionych Katowic). Praca doktorska (maszynopis), Katowice 2002.

[14] Lampert W. and Sommer U.: Ekologia wód śródlądowych. Wyd. Nauk. PWN, Warszawa 1996.

[15] Cieśliński R.: [in:] Anthropogenic and Natural Transformations of Lakes. Polskie Towarzystwo Limnologiczne, vol. 3, pp. 53–58, Toruń 2009

[16] Mirek Z. and Trzcińska-Tacik H.: Ekol. Pol. 1981, **29**(3), 343–352.

[17] Wróbel M., Tomaszewicz T. and Chudecka J.: Polish J. Ecol. 2006, **54**(2), 303–309.

SEZONOWE ZMIANY WYBRANYCH PARAMETRÓW FIZYKOCHEMICZNYCH SŁONYCH ZBIORNIKÓW WODNYCH (NA PRZYKŁADZIE ZBIORNIKA RETENCYJNO-DOZUJĄCEGO „BRZESZCZE")

[1] Katedra Geografii Fizycznej, Uniwersytet Śląski
[2] Instytut Ochrony i Inżynierii Środowiska
Akademia Techniczno-Humanistyczna w Bielsku-Białej

Abstrakt: Praca przedstawia wyniki badań parametrów fizykochemicznych wód (temperatura, pH, konduktywność (przewodność), zasolenie, natlenienie, zawartość chlorofilu *a*, mętność) w zbiorniku pochodzenia antropogennego.

Przeprowadzone badania wykazały, że antropogenne słone zbiorniki wodne charakteryzują się specyficznymi procesami limnicznymi. Dotyczy to w szczególności procesów miksji, które są zupełnie inne niż w naturalnych akwenach wodnych. Zbiornik retencyjno-dozujący „Brzeszcze" należy zaliczyć do typu bradymiktycznego o przewadze stagnowania nad mieszaniem. Różnice w konduktywności pomiędzy przydennymi a przypowierzchniowymi wodami w obrębie 3 metrów głębokości wahają się od 5,4 mS · cm^{-1} do 11,8 mS · cm^{-1}. Wody charakteryzowały się również silnym spadkiem natlenienia wraz z głębokością i między porami roku z ponad 22 mg O_2/dm^3 do około 1 mg O_2/dm^3. Sytuację hydrologiczną w zbiorniku „Brzeszcze" można w pewnym sensie porównać do tych, jakie panują u ujścia rzek do mórz. W zbiorniku tym występują specyficzne procesy ruchu wód, które można by określić jako antropomiksja. Inną niezwykłą cechą są krótkookresowe, zachodzące w ciągu 5 min, duże zmiany konduktywności i mętności, związane prawdopodobnie z falowaniem wywołanym przez wiatr.

Słowa kluczowe: procesy limniczne, wody słone, zbiorniki antropogenne, halofity