Persistance of Meromictic Stratification in Post Mining Lakes

Klaus Joehnk[1], Wilfried Uhlmann[2]

[1]*CSIRO Land and Water, Canberra, Australia,,*
Klaus.Joehnk@csiro.au
[2]*IWB Dresden, Germany,*
Wilfried.Uhlmann@iwb-dresden.de

Extended Abstract

Water quality in future mining lakes strongly depends on their thermal and chemical stratification. High salinity groundwater inflow accumulating in the deepest parts of the lake can generate a permanent stratification, a monimolimnion [1, 2]. However, turbulence generated by wind action and convective mixing during cooling periods in autumn and winter will deepen and on the long run can dissolve the chemocline, thus leading to an overturn of the water column. In general the persistence of meromixis in pit lakes is dependent on the interplay of external factors (climatic conditions, groundwater inflow), as well as internal processes like turbulent mixing and possibly double diffusive convection [3, 4]. The build-up of a monimolimnion might or might not be a desired feature of mine pit rehabilitation. The question then arises, under which conditions and on what time scale such a permanent stratification is persistent. The knowledge of these hydrodynamic processes and their time scales will allow for better management of mine lakes.

Here we use a one-dimensional, vertical lake mixing model (LAKEoneD) capable of including other biogeochemical processes and successfully used in mine pit simulations [5, 6, 7]. It is driven by hourly meteorological data and parameterized by chemocline depth and salinity of the monimolimnion to simulate thermal and salinity stratification in a lake over periods of up to fifty years. The lake model is based on a one-dimensional formulation of k-epsilon closure and the vertical description of heat and momentum exchange solved on a vertical grid with 0.5 m resolution using time steps in the range of 300 seconds. Meteorological drivers like air temperature, irradiance, wind speed, relative humidity and cloudiness or longwave radiation are given as hourly time series available from a nearby meteorological station. The model simulates thermal and salinity stratification over several decades. Results are then analysed for the development of the chemocline depth over this time period. Driving the model with different types of climate input – chosen here as individual meteorological years representing different climate conditions – repeated over half a century results in empirical relations of meromictic persistence in relation to chemocline depth and salinity gradient.

Simulations using a set of 15 salinities in the range of 0 - 10 g/L, a set of 21 chemocline depths between 1 - 50 m and 30 years of meteorological data were run for a future post mining lake as they are created, e.g., in the Lausitz lignite mining district, Germany. The analysis of the ~10000 lake simulation runs shows a consistent pattern of overturn in such possibly meromictic post mining lakes after several years or decades whenever there is no additional saline inflow maintaining the permanent stratification. The generated catalogue of timings of lake overturn in relation to salinity structure and chemocline depth can serve as lower bound for the time scale of meromictic persistence in post mining lakes.

Key words: Pit lake, meromixis, turbulent mixing, hydrodynamics, lake model

References

[1] Schultze M., Pokrandt K.H., Hille W.: Pit lakes of the Central German lignite mining district. Creation, morphometry and water quality aspects. Limnologica 40, 148–155, 2010

[2] Dietz S., Seebach A., Jöhnk K.D., Boehrer B, Knöller K, Lessmann D.: Meromixis in mining lake Waldsee, Germany: hydrological and geochemical aspects of stratification. Verh. Intern. Verein. Limnol. 30, 485-488, 2008

[3] Pieters R., Lawrence G.A.: Physical processes and meromixis in pit lakes subject to ice cover. Canadian Journal of Civil Engineering 41, 569–578, 2014

[4] Boehrer B., Dietz S., von Rohden C., Kiwel U., Jöhnk K.D., Naujoks S., Ilmberger J., Lessmann D.: Double diffusive deep water circulation in an iron-meromictic lake. Geochem. Geophys. Geosys. 10, 2009

[5] Jöhnk K.D.: 1D hydrodynamische Modelle in der Limnophysik - Turbulenz, Meromixis, Sauerstoff (1D hydrodynamic models in limnophysics – turbulence, meromixis, dissolved oxygen). Habilitation thesis, Technical University Darmstadt, 235 pp, 2000

[6] Stepanenko V., Jöhnk K.D., Machulskaya E., Perroud M., Subin Z., Nordbo A., Mammarella I., Mironov D.: Simulation of surface energy fluxes and stratification of a small boreal lake by a set of one-dimensional models. Tellus A 66, 2014

[7] Nixdorf B., Bäuerle E., Heege T., Hofmann H., Jöhnk K.D., Lessmann D., Uhlmann W: Tagebausee Inden II – Entwicklung der Wasserqualität und der resultierenden limnologischen Eigenschaften (Mining lake Inden II – Development of water quality and resulting limnological characteristics). BTU Cottbus, Report for Bezirksregierung Köln und RWE Power AG, pp. 115, 2005