Education and Culture
Lifelong Learning Programme
ERASMUS

ECOLOGICAL STATE OF THE LAKE DURING RESTORATION MEASURES

Physico - chemical properties of the waters of Lake Durowskie

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Introduction

For the total surface of the Earth, 71% it is covered by water and only 2,75 % from this percentage is represented by freshwater. Freshwater is essential for human life and also for many natural systems that support human well-being. Expanding human activity such as industry, agriculture, tourism, recreation, has extensively altered the planet's freshwaters, with modifications impacting the physical, chemical and biological features of aquatic systems.

Durowskie lake is a postglacial lake elongated in shape and is located in Chodzieskie lake region, in Wągrowiec (Central Poland). The lake covers an area of 143 ha and represents an important part of Wagrowiec landscape (Table 1). It is a local ecosystem which is used for fishing, recreation, tourism, education and research. Struga Golaniecka River flows through the lake, supplying it with nutrients from the catchment areas. The lake catchment area is typically agricultural and it's covered by forest. The water quality suffers because of anthropic activities in and around the lake such as nutrient inputs from the surrounding agricultural areas, inflow from the upstream lakes.

Most of lakes around the world are destroyed by eutrophication. Durowskie lake is degraded too. Assessment of water quality can be a complex process undertaking multiple parameters. This report shows present trophy state of lake by trophic state index (TSI). TSI is the most popular index based of physico-chemical parameters.

Therefore, the objectives of this study are to:

- Investigate the current physic-chemical condition of lake;
- Show trends in water quality over time;
- Ascertain nutrients loads coming in and out of lake.

Surface	143.7 ha
Volume	11,322,900 m^3
Maximum depth	14.6 m
Average depth	7.9 m
Main tributary	Struga Golaniecka
Surface of the entire sampling area	236.1 km^2
Surface of the direct catchment area	1.581 ha
Share of agricultural area	58.26 %
Share of forests	33.52 %
Urban area	8.25 %

Table 1- Main characteristics of Lake Durowskie

2. Methods

2.1 Field work

The anthropic activity in Durowskie Lake has a higher level, so the ecosystem and the water quality it's damaged. To see the level of the water nutrients we have been collected samples each day, for a week of July 2013 (01.07 - 06.07) from eight measurements points: Aerator 1, Aerator 2, Beach 1, Beach 2, Middle 1 and Middle 2, Outflow lake and Inflow lake and from different depths, every one meter from the surface to the bottom of the lake (Fig. 1).
In the field, we performed measurements of pH, temperature, TDS, conductivity, velocity and Oxygen concentration.

Fig. 1: Points of measurement

The basic physic-chemical parameters of the water (temperature, conductivity, concentration of oxygen, turbidity, flow velocity and chlorophyll a as well as pH) were measured at eight lake stations and two river stations (the inflow and the outflow of the lake) using WTW Multi

Parameter Meters for one week. Water samples were also taken for the analyses of ammonium nitrogen, nitrite nitrogen, orthophosphates and total phosphorus.

Flow velocity measurement

The discharge and the flow velocity (m/s) were measured in the inflow of the lake at defined cross sections (m^2) (Fig. 2) . The cross section of the lake was divided into different transects at each point of measurement as shown in the figure below the flow velocity were also measured at different water depth (0.5, 1.0, 1.5, 2.0, 2.5, 3.0) depending on the depth as shown in the figure below, since the velocity varies with transects and depth (Fig. 3).

Fig. 2 – Field mesurement of flow velocity

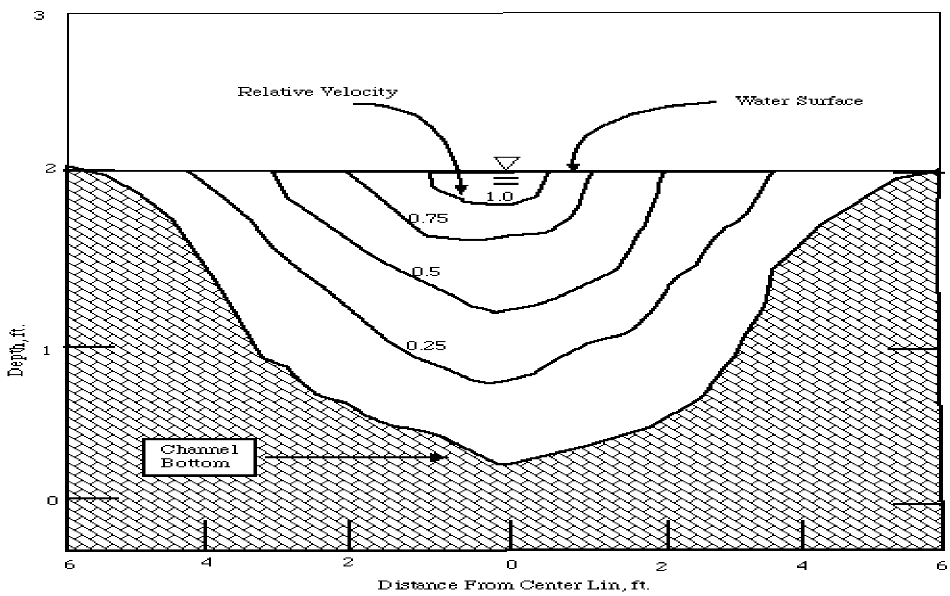

Fig. 3 Distribution of flow velocity in a river cross section (Shaw, 1989)

The characteristics of the river bed (rocky, heterogeneous, sandy, homogeneous etc.) were all taken into consideration when dividing the transects (Fig. 4)

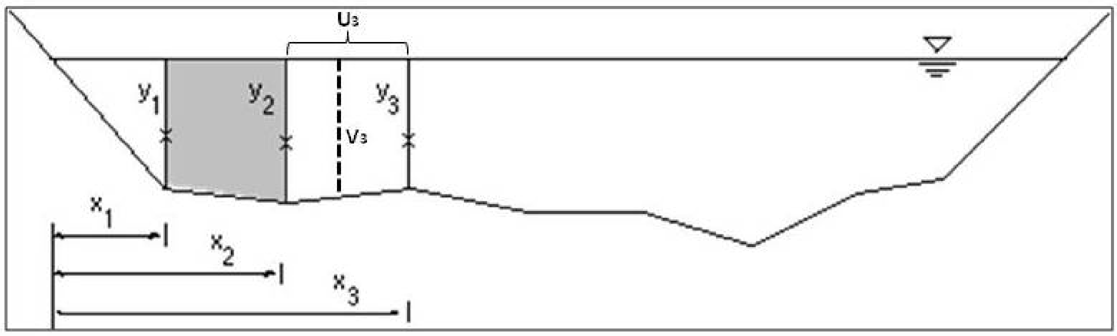

Fig. 4 Subsections of a river cross section to determine flow velocities for each section

Physic- chemical parameters

Water parameters such as pH, conductivity, oxygen content, turbidity (Secchi disc depth) were measured at the various sampling points. Water samples were also taken with the water sampler at depth 0, 1 and 2 meters respectively around aerator 1 for chlorophyll a and nutrient loads (Total Phosphorus, Orthophosphates, Ammonium Nitrogen and Nitrite Nitrogen) measurements.

Turbidity

Turbidity refers to how clear the water is. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. Turbidity indicates the amount of light penetration and provides an indirect measure of the amount of suspended materials in the lake which in many cases gives an indication of the quantity of algae in the water. Turbidity was determined with the Secchi disc (Fig. 5).

Fig. 5: Turbidity measurement with Secchi disk (SD)

Chlorophyll *a* and the nutrient contents:

Replicate samples were taken at each sampling station, two of which were collected at depth 1 and 2 meters and the last at the (0m) surface. The water samples were filtered and stored in the fridge for further laboratory analysis (Fig. 6).

Fig. 6: Water sampler being used to collect water samples at various depths for chlorophyll *a* measurement

pH, Electrical conductivity, Oxygen concentration, Temperature measurements:
WTW Multi Parameter Meters was used to measure directly the parameters above (Fig. 7).

Fig. 7 pH, Electrical conductivity, Oxygen concentration, Temperature measurements with WTW Multi Parameter Meters

2.2 Laboratory analysis

In the laboratory, Chlorophyll *a* samples were processed according to the UWT Chlorophyll Procedure (Strickland and Parsons, 1972) (Fig. 8)
The filters (made by fiber glass), were placed into separated centrifuge tubes with 10 ml of ethanol for 1-2 minutes. After the filters were macerated, the tubes were covered and stored in a dark refrigerator for 18-24 hours (during this time the extraction occurred).
After the extraction period, the samples were centrifuged at 5000 rpm for 15 minutes to separate the chlorophyll a/EtOH solution and the glass fibers. Afterwards the filters were removed and centrifuged again at 2500 rpm for 5 minutes. About 10 ml of the supernatant were transferred to the spectrophotometer cuvette and the transmittance was read at different bands (665 nm, 750 nm - correction for turbidity).
The content of chlorophyll a is calculated with the formula below:

$$\text{Chla } \mu g/l = 29.6[(E^b_{665} - E^b_{750}) - (E^a_{665} - E^a_{750})] * ev/(V \times P)$$

E^a = absorbance, acidified
E^b = absorbance, base
ev = volume of alcohol used in the extraction, in ml
V = volume of filtered sample, in liters
P = path length (Note that this test assumes use of a 1 cm path length).

Fig. 8 – Laboratory analysis of the samples

2.3 Digital analysis

All the graphs and figures were made in the Excel 2010 from the Open Office package.
The trophic state index (TSI) was used to define the trophic status of the lake. The Trophic State Index (TSI) is a classification system designed to "rate" individual lakes based on the amount of biological productivity occurring in the water. Using the index, one can gain a quick idea about how productive a lake is by its assigned TSI number.
The calculation of the trophic state index (TSI) was produced with the following formulas which were assessed by Carlson's Trophic State Index (TSI) equations (CARLSON, 1996).

TSI for Secchi depth: $TSI_{(SD)} = 10 (6 -)$

TSI for chlorophyll a: $TSI_{(CHL)} = 10 (6 -)$

The quantities of nitrogen, phosphorus and other biologically useful nutrients are the primary determinants of a lake's trophic state index (TSI). Nutrients such as nitrogen and phosphorus turns to be limiting resources in standing water bodies. Increasing concentration tend to result in increased plant growth, followed by corollary increases in subsequent trophic levels. Consequently, a lake's trophic index may sometimes be used to make a rough estimate of its biological condition.

3. Results

Results of chlorophyll *a*

Chlorophyll *a* is an indicator of phytoplankton abundance and biomass in lake waters. It can be an effective proxy of trophic status and is a commonly used measure of water quality. High levels often indicate pure water quality and low levels often suggest good conditions.
From the graphic below we observed that the highest concentration of chlorophyll *a* was at the inflow (15 µg/L) and the lowest is at the middle 1 (4 µg/L) (Fig. 9).

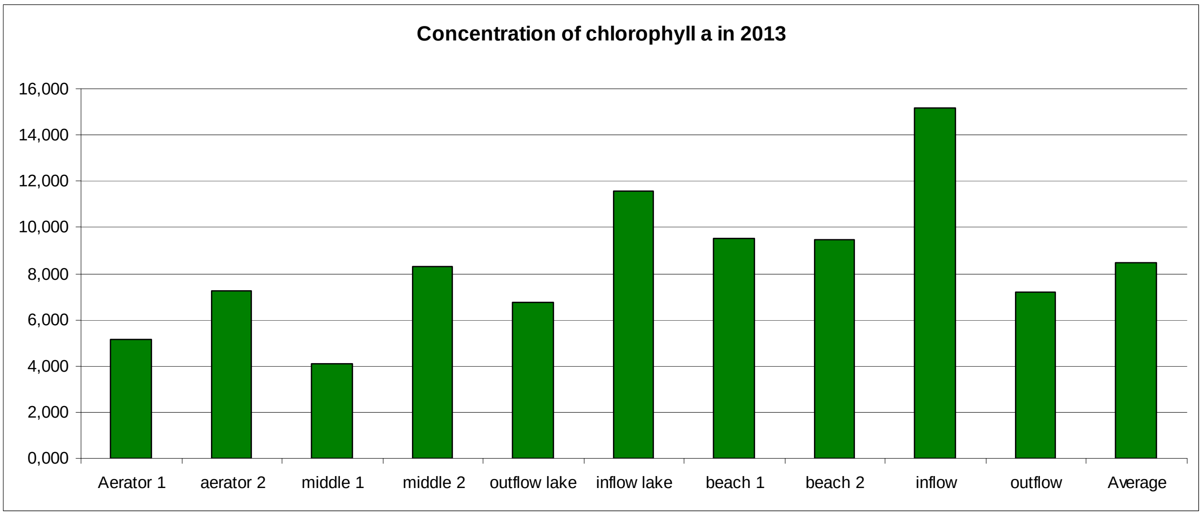

Fig. 9 – Concentration of Chlorophyll *a*

The lowest value of transparency was recorded at the lake close to the Inflow (Struga Gołaniecka) which was 1.0 m. The highest, the best transparency was 2.5 m located near the Beach 2 (Fig. 10). Average water transparency of Lake Durowskie is 1.68 m

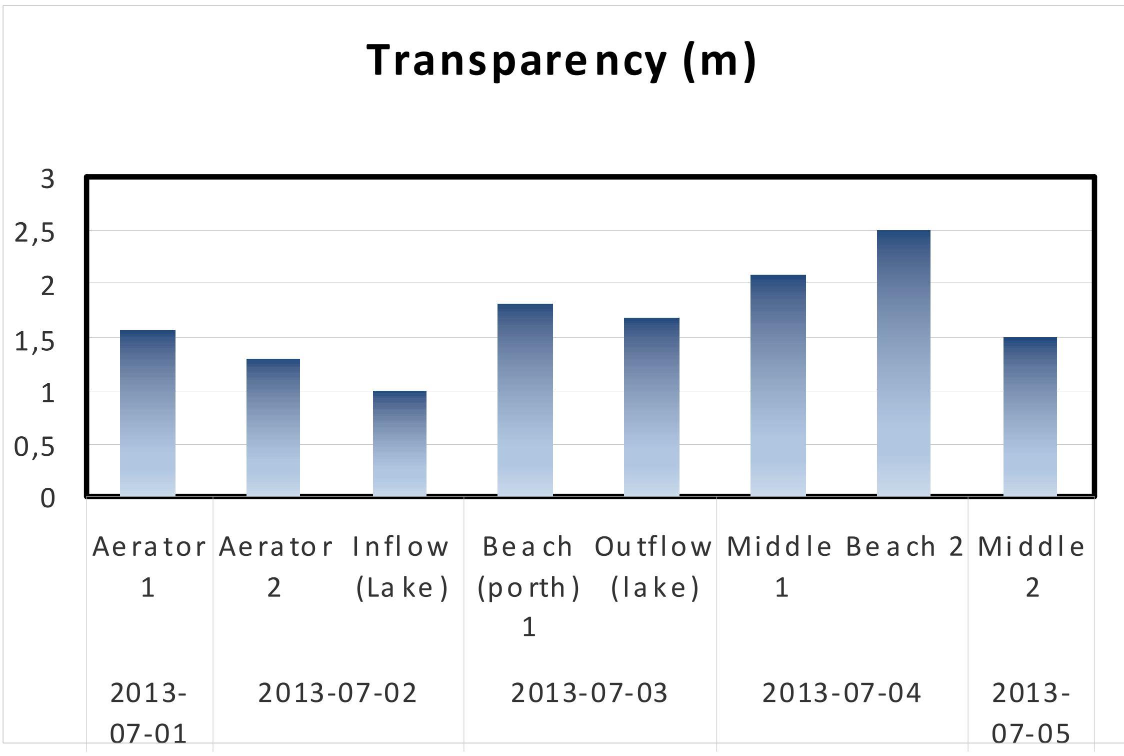

Fig. 10 – Transparency level

The water temperature is between 24.5°C and 6.1°C. In different sampling points temperature varies slightly, from 4 to 6 meters we can observe a thermocline (from 20° to 10°C) (Fig. 11).

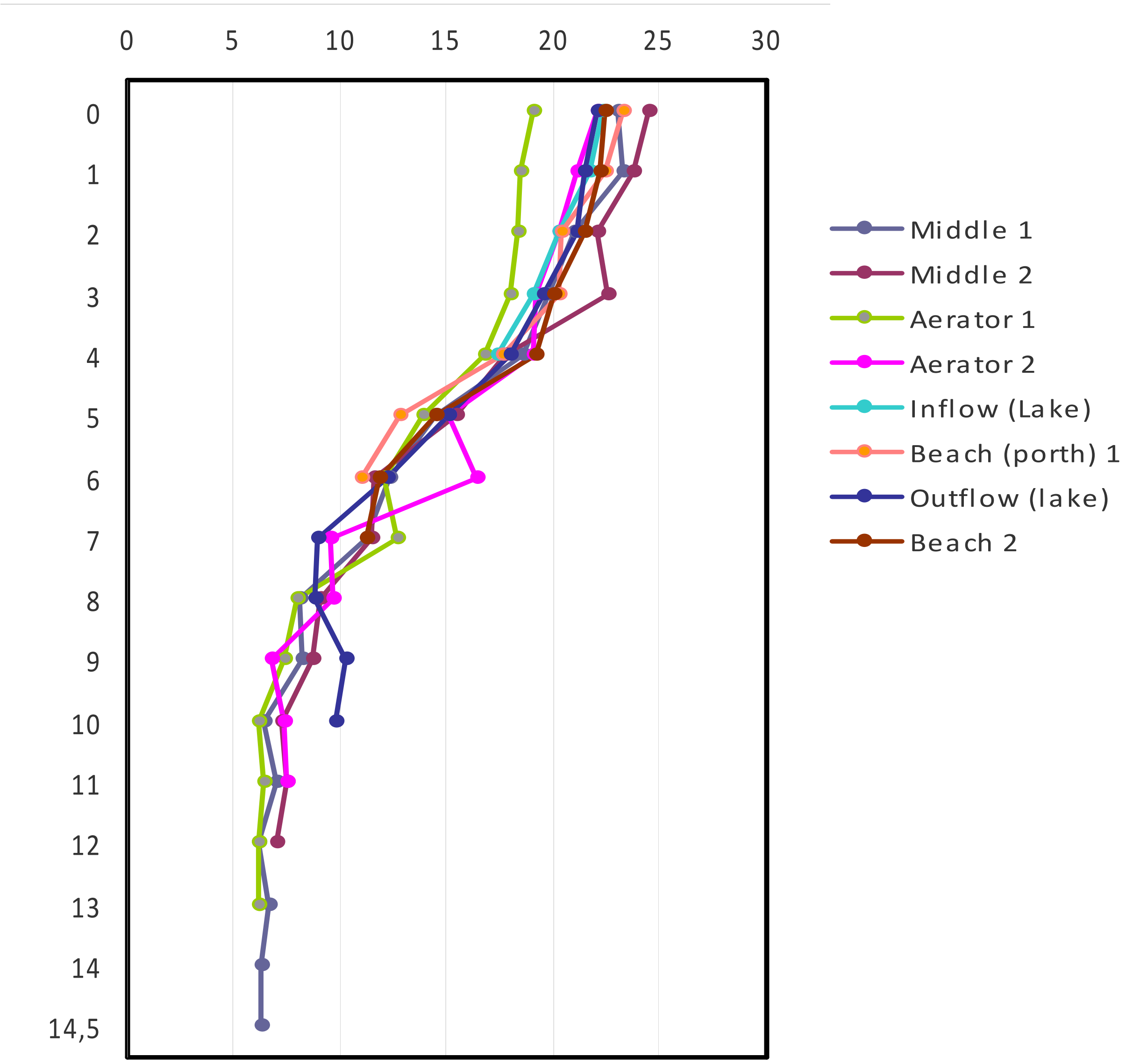

Fig. 11 – Temperature variation

The pH - value varied between 8.57 and 7.18. The pH did not vary so much between different stations and it's negatively correlated with the depth (Fig 12).

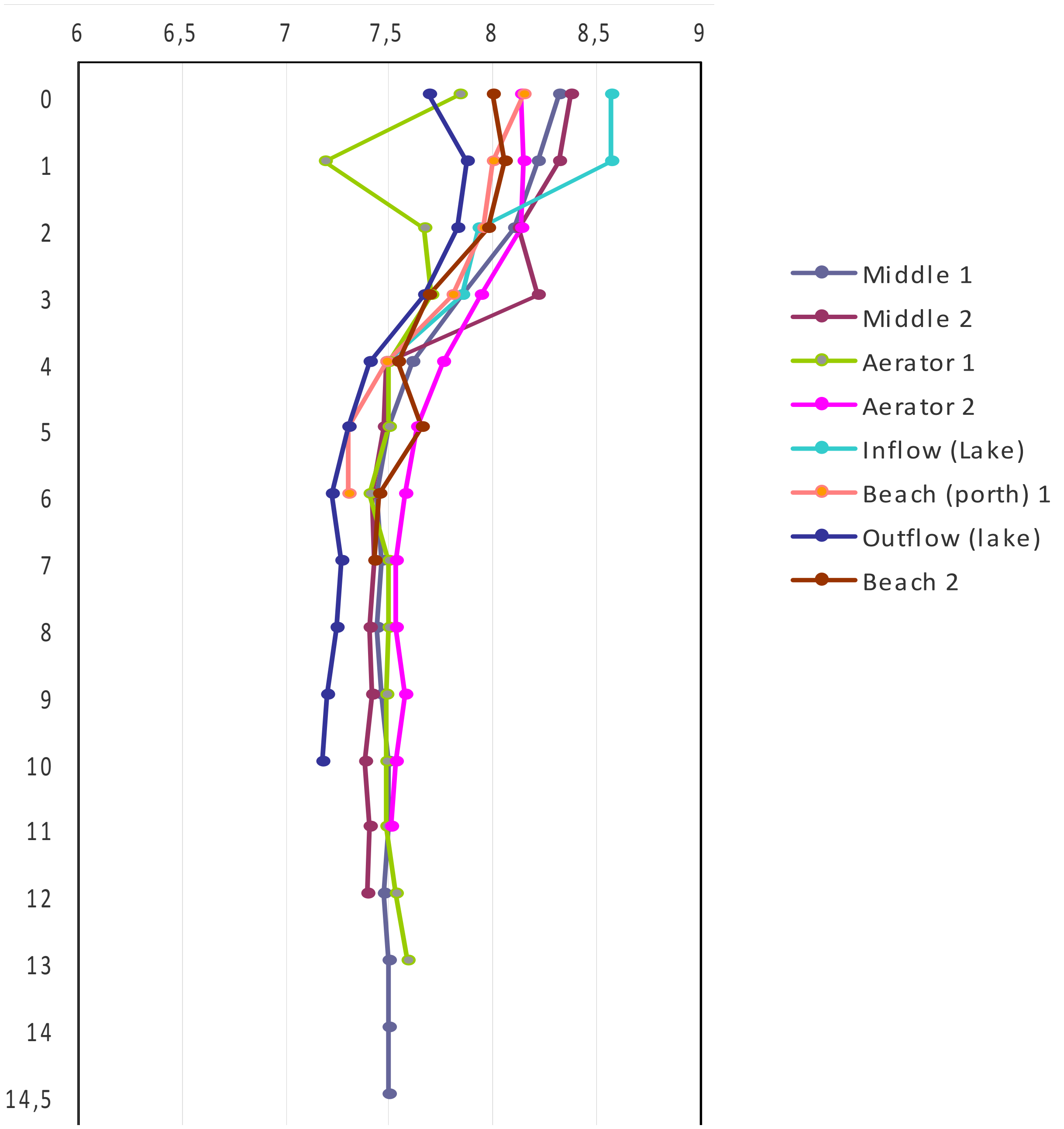

Fig. 12 – pH values in different sites

The conductivity values ranged between 697 µs/cm and 435 µs/cm in the different sites. The conductivity decreased with the depth. (Fig. 13)

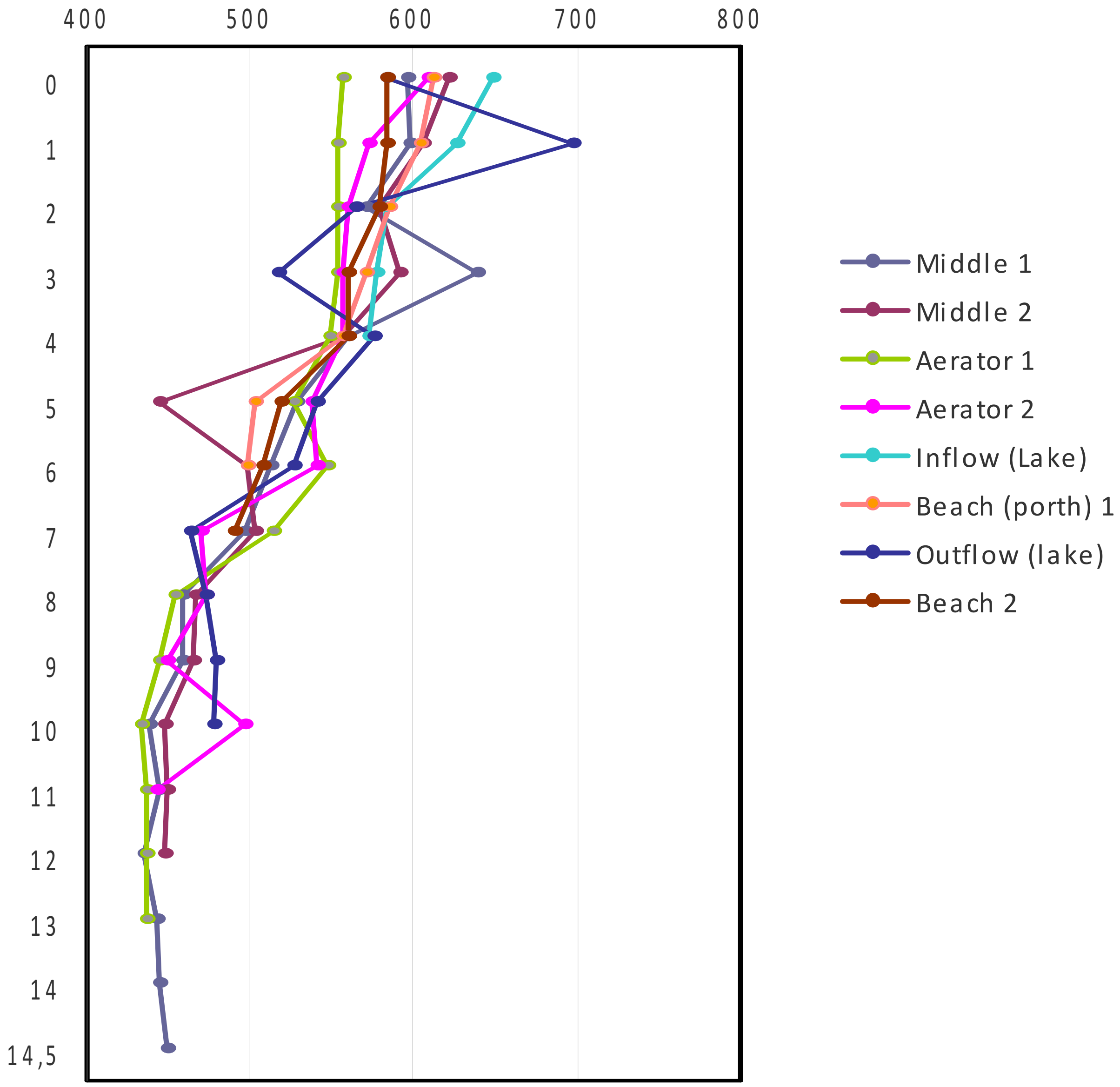

Fig. 13 – Conductivity levels

The dissolved oxygen (DO) value is between 80 mg/l and 11.3 mg/l. From the graphic below we observed that the highest value it's on the inflow at the depth of 1 m and the lowest one on the beach 2 at 4 m depth.

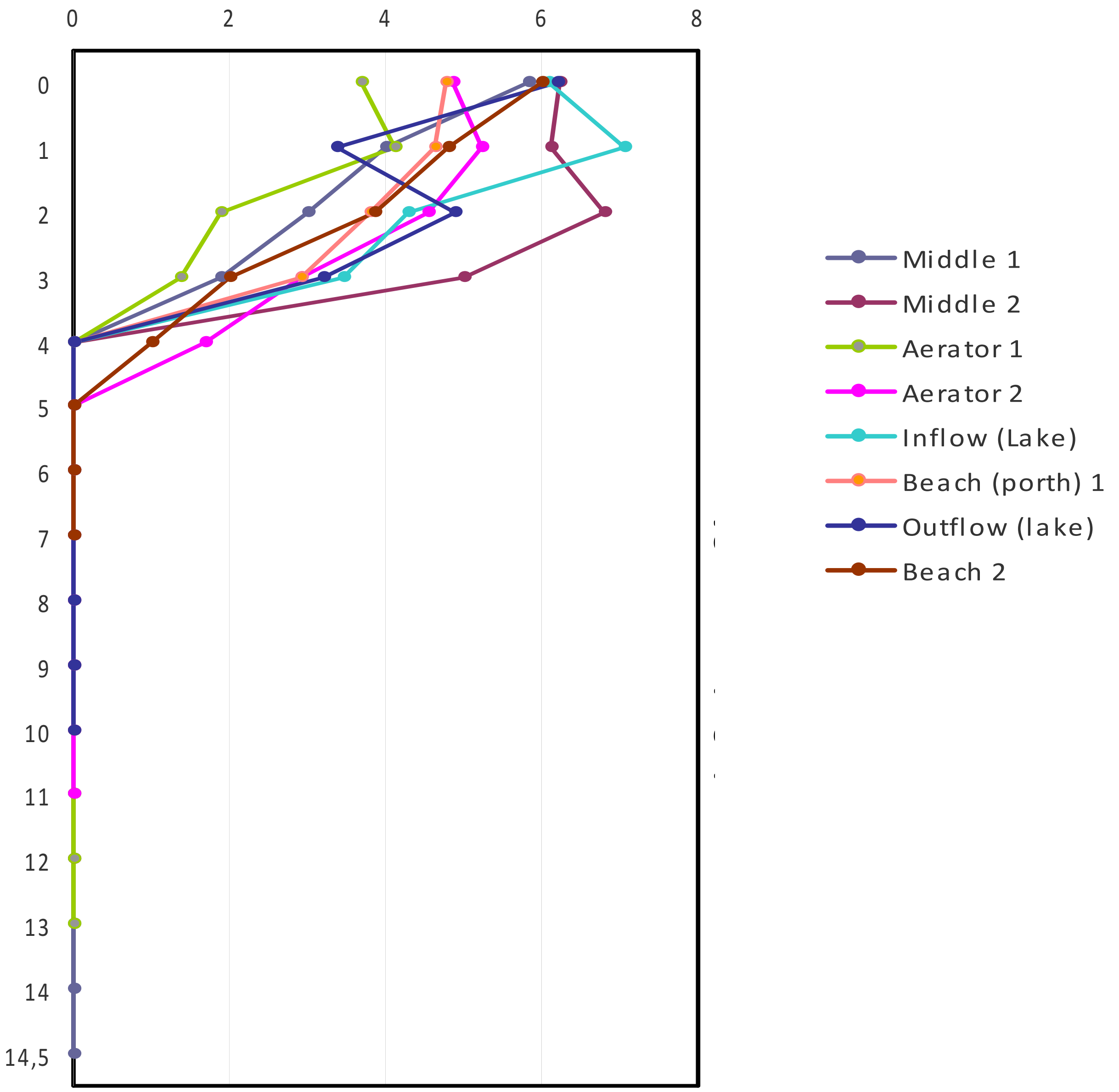

Fig. 14 Dissolved Oxygen concentration

TDS value was positively correlated with the depth, with an average value of 467.31 mg/l (Fig. 15)

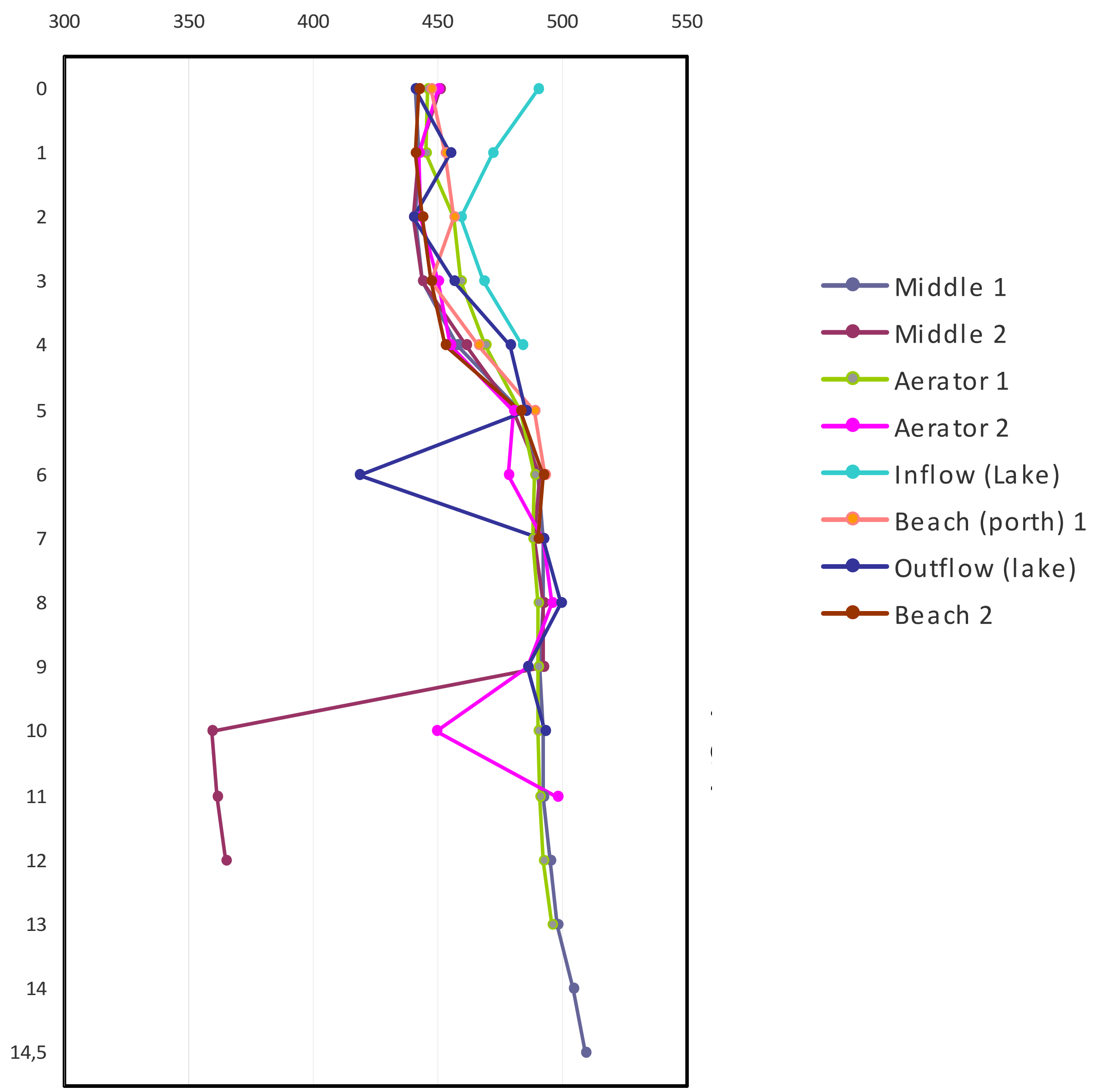

Fig. 15 TDS values

Nitrogen is one of the primary nutrients that in excessive amounts can pollute a lake, and it is also essential to the production of plant and animal tissue. As observed in Fig 16, the quantity of Nitrogen in the inflow is higher than in the outflow. This suggests that a large quantity of nutrients is entering the lake.

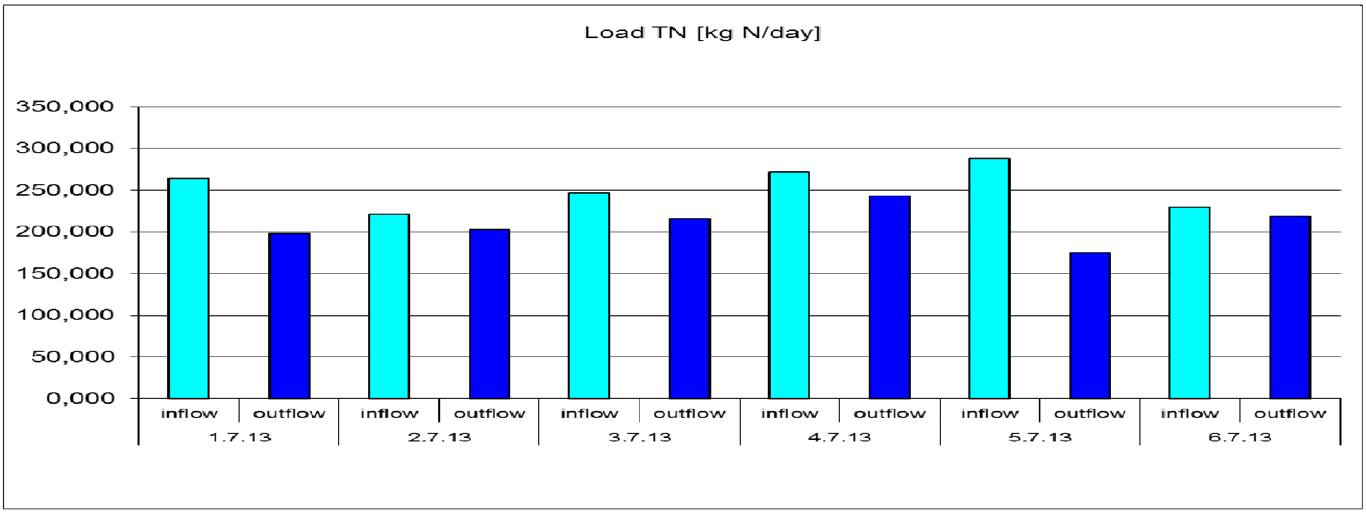

Fig. 16 – Total load of Nitrogen

he graphic below (Fig. 20) illustrated the fact that the concentration of chlorophyll *a*, compared with 2012 increased dramatically in all stations, and compared to 2011 is slightly reduced at all measurement points. Only the Inflow is an exception, where chlorophyll *a* concentration increased slightly as compared to the results obtained two years ago. Average concentration of chlorophyll a in Durowskie Lake was 8, 45 µg/l (Fig 16).

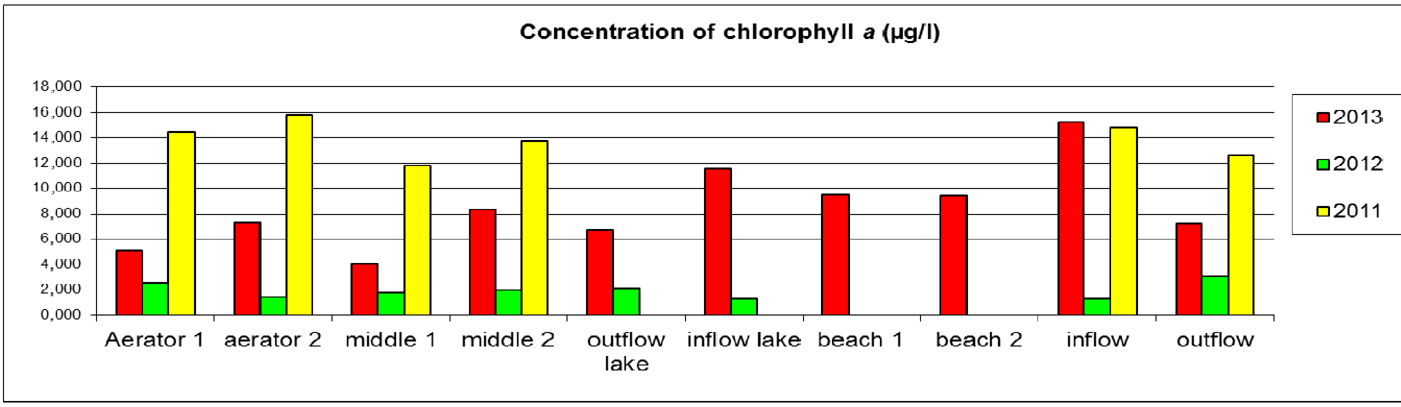

Fig. 20 – Chlorophyll *a* concentration from the last three years

Chlorophyll *a* and transparency (Secchi Depth) can be used as indicators of trophic state of the lake which is assessed by Carlson's Trophic State Index (TSI) equations (Carlson and Simpson 1996).

The charts below present the values of TSI for river (Fig. 17) and lake (Fig. 18 and Fig. 19). TSI counted from Chlorophyll a method showed that condition of lake is worse this year in comparison with 2012 but is better than 2011. TSI calculated using Secchi Disk method showed an improvement from 2012 but the conditions are worse than 2011.

$TSI_{Chl\ a}$ for River

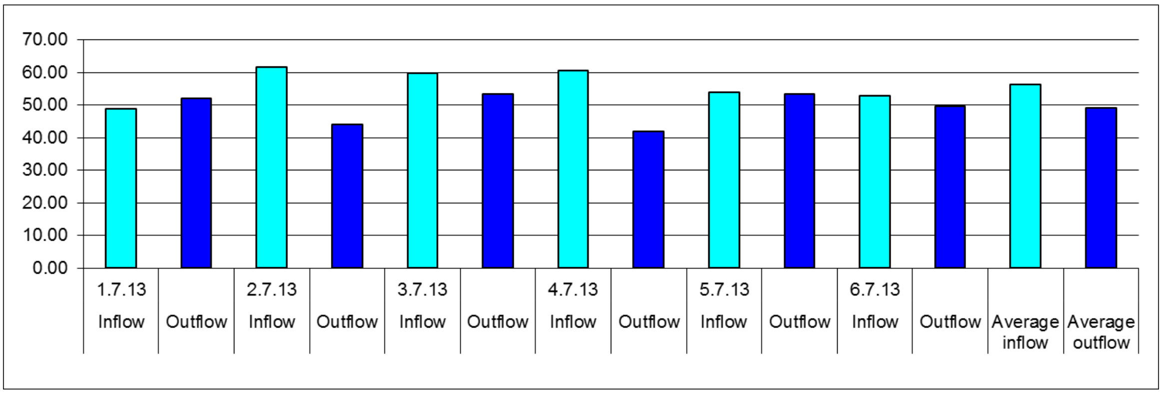

Fig. 17 – TSI values for river (Chl *a* method)

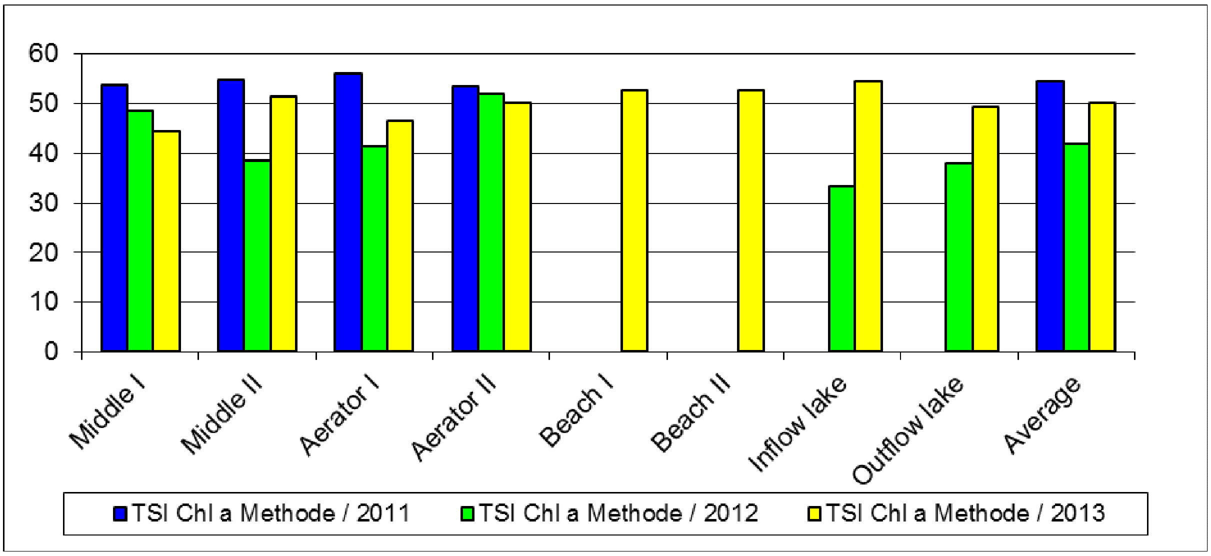

Fig. 18 – TSI values for lake (Chl *a* method) in the last 3 years

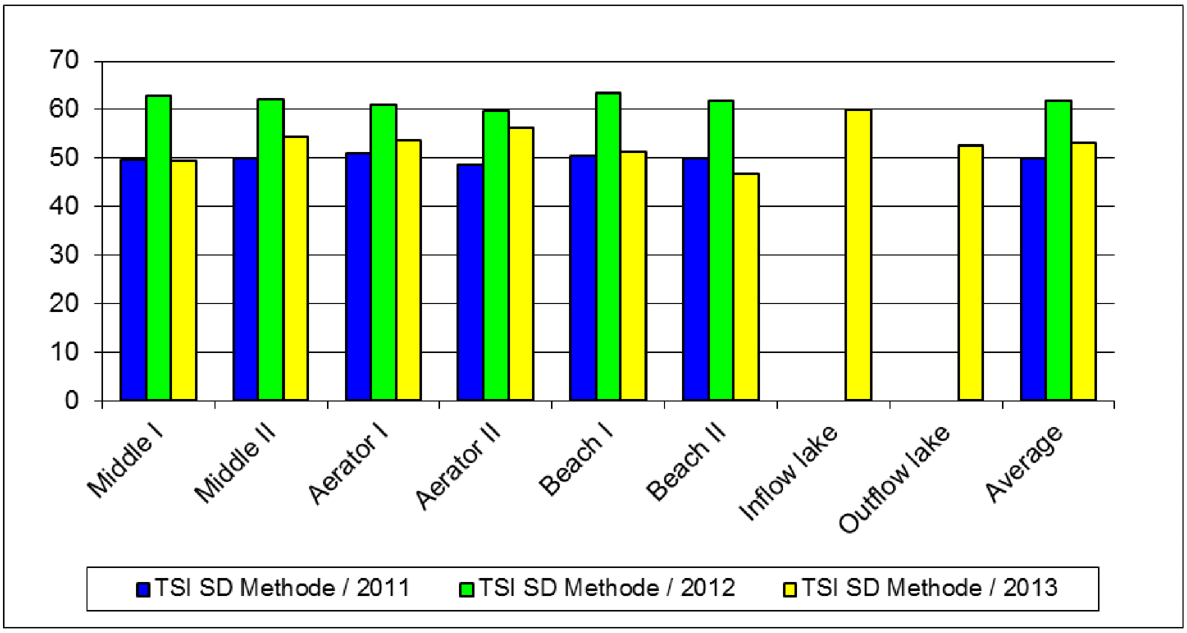

Fig. 19 – TSI values for lake (SD method) in the last 3 years

4. Discussions

4.1. How do the parameters interact with each other and what is the water quality according to the Water Framework Directive?

Almost in all the days during the measuring period the weather was good, with sunshine, with only a few clouds and rain. With the sun, the temperature of the lakes surface water is over 20°C. The sampling points show no significant variation, because they all get the same amount of sun during the morning. With increasing depth, the temperature is decreasing. First it decreases slightly and then very fast from 4m to 6m. This temperature change indicates the different zones in a lake (epilimnion, metalimnion, hyperlimnion). At the surface there is the epilimnion with relatively high and constant temperatures and then there is the metalimnion with a fast decrease in temperature. In the hyperlimnion (7m to bottom) there is almost no change in temperature anymore (WALTER 2002).

With the increase of depth it is not only getting colder, but also the amount of dissolved oxygen, the pH-value and electrical conductivity are decreasing. Dissolved oxygen is higher at the surface out of different reasons. First here it is possible to increase the DO by weather changes, e.g.: wind, waves, rain etc. and the epilimnion is affected by turbulences of for example boats. Second, the epilimnion is where most algae grow. Algae need light, nutrients and a warm temperature (SEIP 1990). Dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobe life forms. As dissolved oxygen levels in water drop below 5,0 mg/l, aquatic life is put under stress.

Our results can be different from the ones obtained in the past years because of the change of methodology and devices. The presence of algae in the upper parts of a lake is one reason for the increased pH values near to the water surface. Usually a water body is more acid because of the carbondioxid in the water. Algae use this carbondioxid for their metabolism and therefore the pH is getting more basic.

Following table determines the classes after the Water Framework Directive (values especially for Poland). For Secchi depth, dissolved O2 in hypolimnion and el. Conductivity there is no specification in classes, but in “good” and “bad”.

Tabel 1. Classes of Water Framework Directive

Ecological state of	water	Good		Bad		
Parameter	Class of water	I	II	III	IV	V
Chlorophyll *a*	(µg/L)	<7,0	7,0-13.0	13,0-21,0	21,0-33,0	>33
Secchi	(m)	>1,7		<1,7		
Dissolved O_2	(mg/L)	>4		<4		
Conductivity	(µS/cm)	<600		>600		

In Lake Duroskie we found the following classes:

Tabel. 2 Evaluation of Lake Durovskie

Parameter	**Value**	**Classification**
Chlorophyll *a*	≈ 8.45 µg/L	Good (II class)
Oxygen concentration	≈5.47 mg/L	Good
Conductivity	≈525.8 µS/cm	Good
Secchi disc	≈1.68 m	Bad

According to Water Framework Directive, chlorophyll *a* value of 8,45µg/L is normal and in class II. The transparency with a value of 1,68 m is evaluated as “bad” but it is near the normal value, also the DO is bad. The conductivity, with an average value of 535,73 is rated like “good”.

4.2. What is the trophic state of the lake according to the trophic state index (TSI)?

The TSI average value according with Secchi Disk is 53.06 and the average TSI for chlorophyll *a* is 50.22. These values are at the line between mesothrophic and euthrophic lake.

Table 3. – TSI index

Trophic state	Oligotrophic	Mesotrophic	Eutrophic	Hypertrophic	Durowskie Lake
TSI Value	<40	40-50	50-70	>70	TSI SD= 53.06 TSI Chl *a*=50.22

4.3. How did the lake develop in the last year?

In the figures above (Fig. 18 & Fig. 19) we can observe the changes of TSI values in the last three years. TSI measured with Chlorophyll *a* method shows that condition of lake is worse this year in comparison with 2012 but is better than 2011. TSI calculated using Secchi Disk method shows an improvement from 2012 but the conditions are worse than 2011. According with Chlorophyll *a* method we can say that Durowskie Lake is euthrophic, but the TSI value is very close to the limit of mesothrophic lakes.

4.4. What are possible management improvements for the lake?

The management of the lake Durowskie is a difficult task and there is no guideline to manage the lake in the right way. According to our work and research results, the problem with the water quality it's not only from the inside, but from the lakes above. One of our recommendations is that the local authority should take action on how to prevent pollution from the northern lakes. There are several households which are still not connected to waste water plants. Improving the ability to have access to water plants could therefore improve the lakes quality in a long term sight. Another problem is the too high anthropogenic pressure; the managers should reduce the activities on the lake (hydro biking, motor boats etc.) and manage the gaps created by fishermen (they are destroying the macrophytes belt).

5. Conclusion

This research work concludes that the water quality of Lake Durowskie does not satisfy all the demands of the Water Framework Directive.

The classification of the water class is based on chlorophyll *a* measurements and gives a classification of II. However, chlorophyll *a* can fluctuate rapidly and shows only the current state of the water and no long term developments. The quality of the lake according to dissolved O_2 must be evaluated as “good”.

Although the Secchi disk measurement is classified as “bad” the value (1.68m) is very close to the limit between “good” and “bad” (1.7m). The conductivity is evaluated as “good”.

The north part of the lake is in relatively worse condition; also the beaches from the southern part are in much bad condition than the center part of the lake. Although the general condition of the lake is similar like two years ago, we can say that Duroskie still to be in eutrophic state.

In summarizing it can be stated that Lake Durowskie is on a good way, but still needs further improvements and a longer time period in order to fit the European water framework directive.

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