Report

Water Quality in Lake Durowskie 2010

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I. Introduction

Lake Durowskie is one of the most attractive landscapes in Wągrowiec, Poland. It considerably contributes to the income of the town by recreation and tourism services such as fishing, swimming, boating, and so on. Besides that, it benefits local residents with cool climate, resting and sporting places, aesthetic quality. However, these activities may threaten lake development, which can directly or indirectly affect human health and well-being in return. Therefore investing water quality of the lake is very important for its development as well as livelihood improvement.

Most of lakes around the world are often degraded by eutrophication. In order to evaluate the trophic state of the lake, many methods was created, among them TSI is the most popular application.

This report is aim to evaluate the present trophic state of the lake by trophic state index (TSI) based on physic-chemical parameters data and to compare the trophic states through measured years. Management strategies are also suggested for the sustainable use of lake resources.

II. Methods

Lake Durowskie is a shallow lake (14,6m depth) with the whole catchment area of 236.1 km^2. Water samples were taken from indicated locations with different depth. Sampling sites and characteristics of the lake are shown in figure 1. Temperature, conductivity, dissolved oxygen (DO), total dissolved solid (TDS) was measured in situ by computer sonde of the YSI incorporated type (556 MPS). Secchi disc was used to measure transparency (SD). Furthermore, Nitrate, Phosphate and chlorophyll-a (Chla) concentration and was analysed in laboratory by Spectrophotometer. Chlorophyll-a concentration was determined fluorometrically according to Strickland and Parsons (1972).

Surface	143.7 ha
Volume	11,322,900 m^3
Max depth	14.6 m
Mean depth	7.9 m
Main tributary	Struga Gołaniecka
Surface of the whole catchment area	236.1 km^2
Surface of the direct catchment area	1,581.3 ha
Share of agricultural area	58.26%
Share of forests	33.52%
Urban area	8.25%

Fig 1. Characteristics of the lake and sampling stations

Chlorophyll a, total Phosphorus and transparency are used as indicators of trophic state of the lake which was assessed by Carlson's Trophic State Index (TSI) equations (Carlson and Simpson 1996).

$TSI_M(Chl\ a) = 9.81 \ln(Chla) + 30.6$ *(1)*

$TSI_M(TP) = 14.42 \ln(TP) + 4.15$ *(2)*

$TSI_M(Sd) = 60 - 14.41 \ln(Sd)$ *(3)*

where *Chl a* is Chlorophyll *a* (µg/L), *TP* is total Phosphorus (TP (µg/L)) and *Sd* is transparency (m)

Final result was used to compare with Carlson's Trophic Classicfication (table 1) to determine which ecological status the lake belong to.

Table 1. Classfication of trophic state index (TSI)

TSI_M	**Chl*a*** (µg/L)	**TP (µg/L)**	**Sd (m)**	**Trophic Class**
<30—40	0—2.6	0—12	4—>8	Oligotrophic
40—50	2.6—7.3	12—24	2—4	Mesotrophic
50—70	7.3—56	24—96	0.5—2	Eutrophic
70—100+	56—155+	96—384+	<0.25—0.5	Hypereutrophic

(Carlson and Simpson 1996)

Moreover, physico-chemical parameters can indicate ecological quality of the lake according to Water Framework Directive (WFD).

Table 2. Classification of water quality in lakes and rivers introduced in 2004 according to Water Framework Directive (WFD)

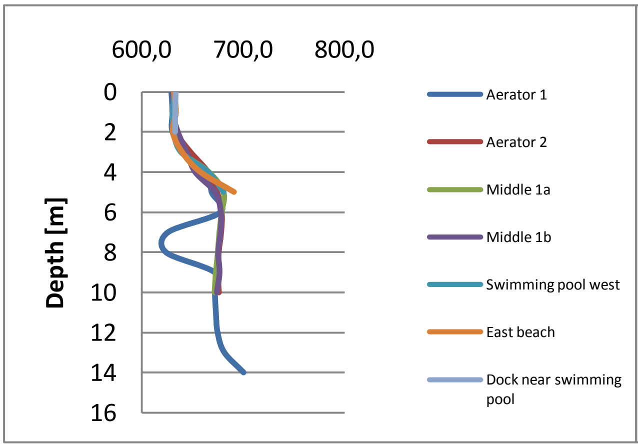
Parameter	Class I	Class II	Class III	Class IV	Class V
pH	6.5 - 8.5	6.0 - 9.5	6.0 - 9.0	5.5 - 9.0	< 5.5 or > 9.0
Suspended solids (mg/l)	<15	15-25	26-50	51-100	> 100
BOD_5 (mg/l)	< 2	2 - 3	3 - 6	6 - 12	> 12
COD_{Mn} (mg/l)	< 3	3 - 6	6 -12	12 - 24	> 24
COD_{Cr} (mg/l)	< 10	10 - 20	30	60	> 60
Dissolved oxygen (mg/l)	> 7.0	7.0 – 6.0	6.0 – 5.0	5.0 – 4.0	< 4.0
Ammonia (mg/l)	< 0.5	0.5 – 1.0	1.0 – 2.0	2.0 – 4.0	> 4.0
NO_2 -N (mg/l)	< 0.03	0.03 - 0.1	0.1 - 0.5	0.5 - 1.0	> 1.0
NO_3 -N (mg/l)	< 5	5 - 15	15 - 25	25 - 50	> 50
PO_4 -P (mg/l)	< 0.2	0.2 - 0.4	0.4 - 0.7	0.7 - 1.0	> 1.0
Ptot (mg/l)	< 0.2	0.2 - 0.4	0.4 - 0.7	0.7 - 1.0	> 1.0
Zn (mg/l)	< 0.3	0.3 - 0.5	0.5 – 1.0	1.0 – 2.0	> 2.0

(BERNET CATCH, 2006)

Management strategies are based on Driver-Pressure-State-Impact-Response (DPSIR) and Participatory skills approaches.

III. Results and Discussion

3.1 Physico-chemical parameters



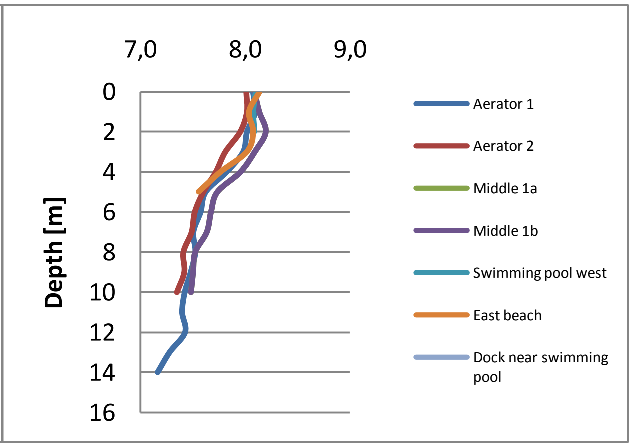
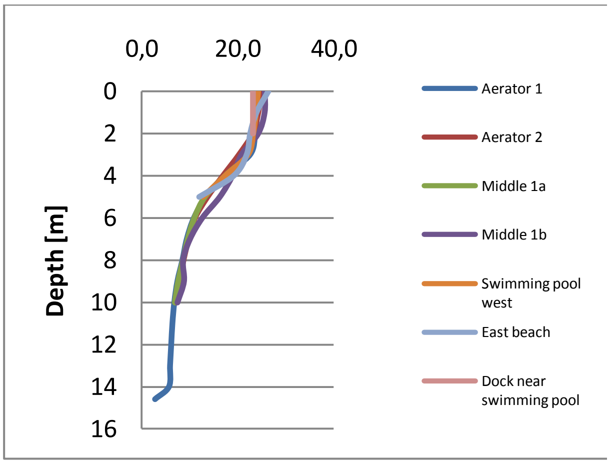


Fig 2. Conductivity (µS/cm *Fig 3. pH*

Conductivity was really high, increasing from around 600 (µS/cm) to nearly 700 (µS/cm). At aerator 1, it suddenly decreased at 7m depth and rose again to the highest value near the bottom (fig 2). In contrast, pH was falling gradually from 8.0 to nearly 7.2 at all sampling sites (fig 3).



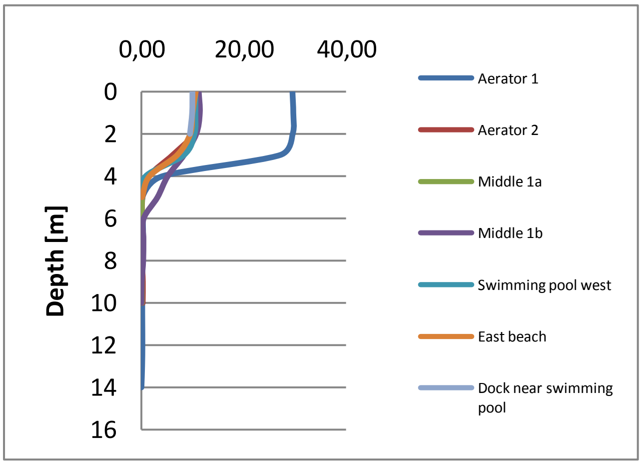
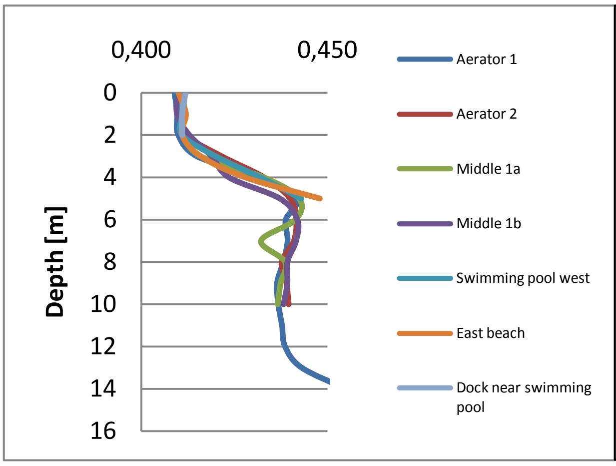


Fig 4. Temperature (^{o}C) Fig 5. DO (mg/L

Temperature and DO concentration decreased dramatically from surface water to 4m depth. There was almost no differences between stations. However, DO profile at Aerator 1 has highest value compared to other stations. From 4m downward, there was almost no dissolved oxygen.



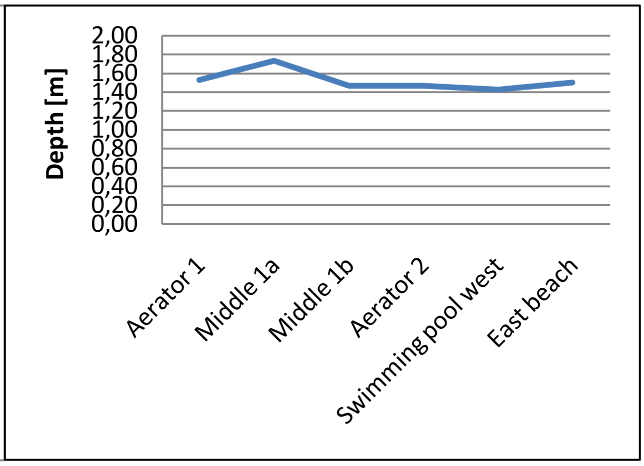
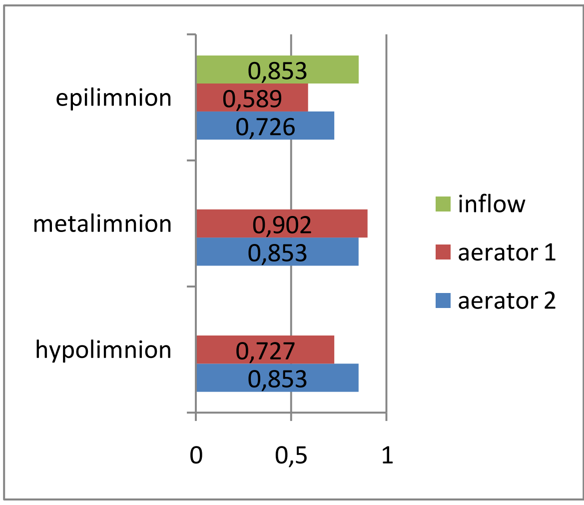


Fig 6. TDS(mg/L Fig 7. SD(m)

TDS increased considerably in epilimnion layer and slowly went up to the highest value at hypolimnion layer. At middle 1a (near the big swimming place) it had slightly change in metalimnion layer (fig 6). Through sampling stations, there was relatively the same value (at around 1.5m), except for highest visibility at station middle 1a (fig 7).

Nitrogen and Phosphorus concentration is the most important factor contributing to eutrophication in water ecosystem. The horizontal and vertical comparison between Nitrogen and Phosphorus inflow and at two aerator (fig 8,9,10) show that nutrient concentration was highest at hypolimnion layer, and inflow water also contributed high nutrient load to the lake.



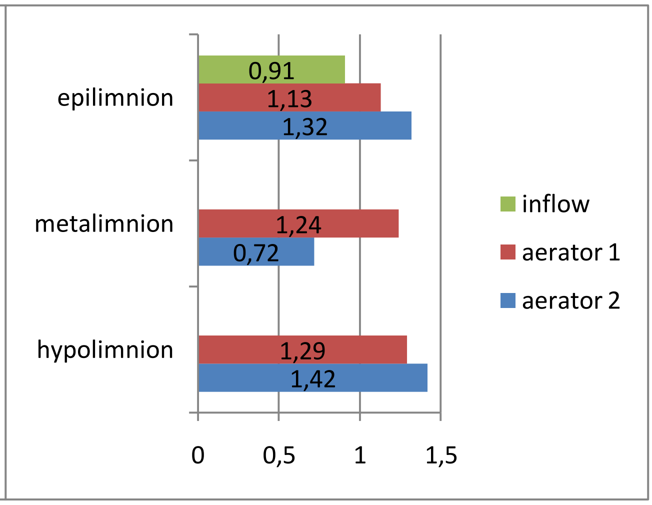


Fig 8. N-NH_4 (mg/L)

Fig 9. N-NO_3(mg/L)

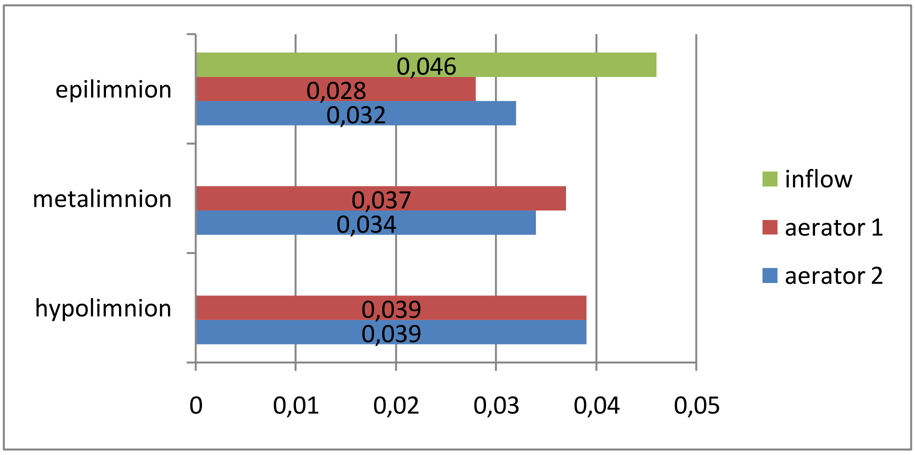


Fig 10. Total Phosphorus (mg/L)

3.2 Trophic state assessment

Water transparency, nutrient concentration, and phytoplankton biomass have been good indicators for trophic state of water because they can show primary production in the lakes. The low clarity can be interpreted as high amount of suspended materials, including phytoplankton or zooplankton and other substances. Therefore, this is the easiest way to diagnose ecological condition of lake Durowskie. TSI can be calcutated based on Secchi disc measurement and equation (3) (table 2).

Table 3. TSI of Secchi

Stations	Depth (m)	**TSI (SD)(m)**	Trophic state
Aerator 1	1.53	53.87	eutrophic
Middle 1a	1.73	52.10	eutrophic
Middle 1b	1.47	54.45	eutrophic
Aerator 2	1.47	54.45	eutrophic
Swimming pool west	1.4	55.15	eutrophic

Swimming pool, west part of lake	1.45	54.65	eutrophic
East beach	1.5	54.16	eutrophic

The TSI(Sd) results show that most of measured stations were eutrophicated. Furthermore, TSI(Chla) and TSI(P) present the same situation (table 4).

Table 4. TSI(Chl a) in different stations in 1m depth

Stations	Chl. "a" [µg/l]	**TSI(Chl) (µg/L)**	PO_4og (µg/L)	**TSI (TP) (µg/L)**	Trophic state
Aerator 1	9.74	52.93	28	52.20	eutrophic
Middle 1a	8.10	51.12			eutrophic
Middle 1b	8.23	51.28			eutrophic
Aerator 2	8.93	52.08	32	54.13	eutrophic

Although the TSI can somehow show the ecological status of water quality, it still has some weakness in describing the overall condition of ecological condition of the lake. However, with the whole view on spatial distribution of these parameters from the inflow to outflow (fig 11), there were small changes of values in stations. The visibility was changing gradually. DO diffences can be explained by different velocity of waterway. It can be concluded that not only water quality inside the lake is eutrophic, but also water quality in inflow and outflow.

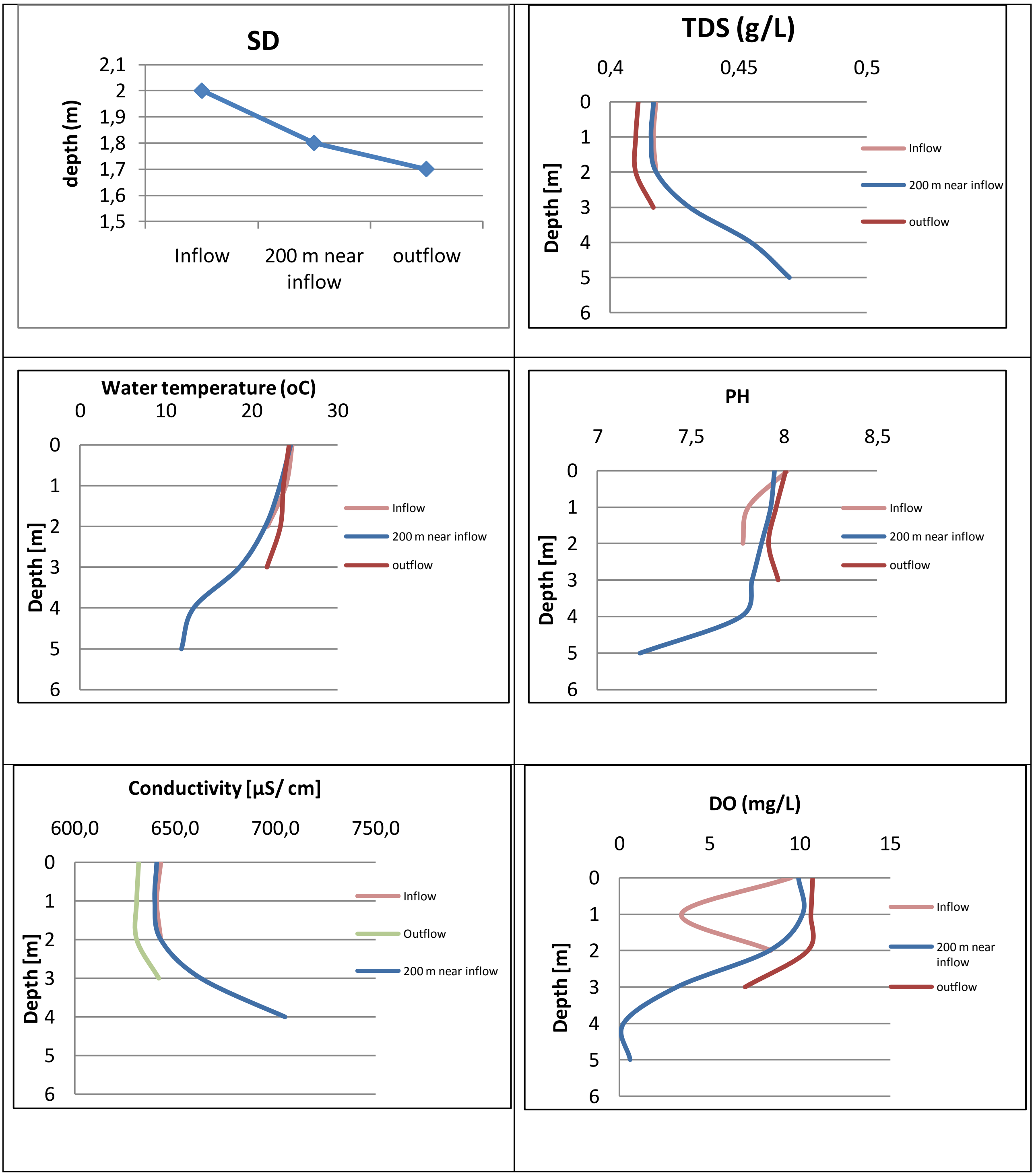


Fig 11. Comparison of parameters in inflow, 200m near inflow and outflow

Compare to WFD??

-Comparison of parameters (...) during 3 years...->evaluate

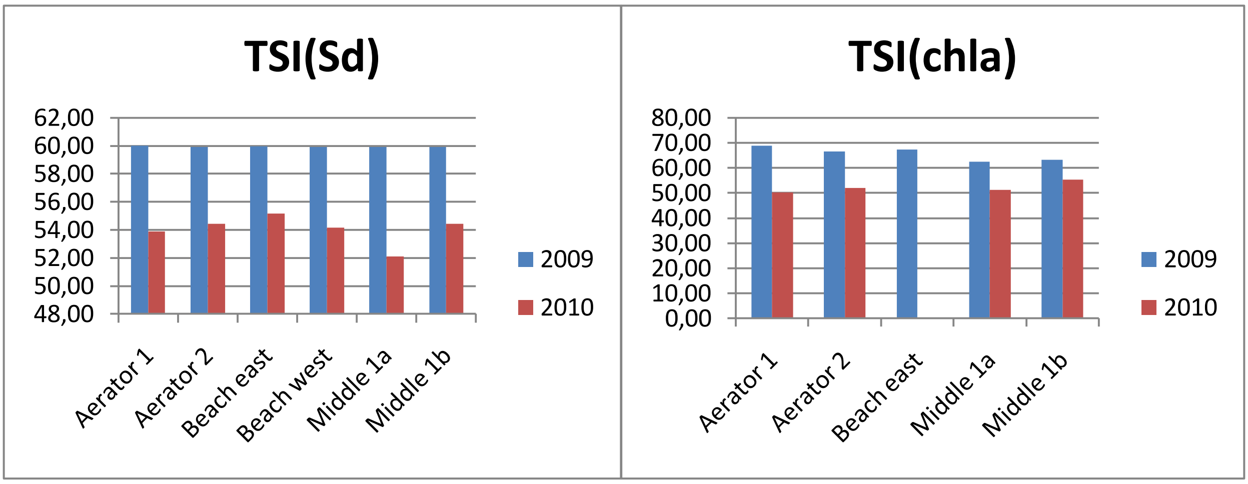


Fig 12. TSI(Sd) and TSI (Chla) changes

As can be seen from figure 12, trophic state of the lake has significant improvement in the whole sampling stations. This can be proved by the falling of Nitrogen and Phosphorus concentration. However, it is difficult to predict the trend of values because of fluctuation of nutrient input from inflow, rain water runoff, and climatic condition. Therefore, reducing the amount of controllable nutrient input as much as possible is to keep improving water quality in the lake.

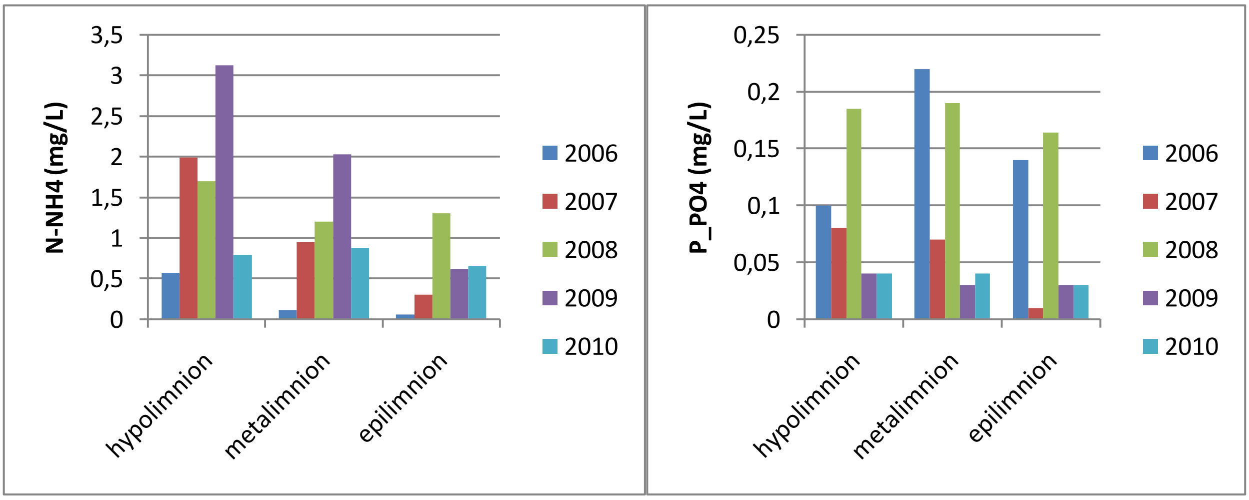


Fig 13. Temporal variability of Nitrogen and Phosphorus

3.3 Management strategies

The reasons for eutrophication of the lake is probably due to pollution transfer from other region nearby through inflow channel. Erosion and runoff along the bank can also make the condition become worse. Furthermore, field observation by counting the number of fishing and swimming places around the lake may discover other drivers of pollution. With almost 103 fishing sites, and 24 swimming sites, the amount of leftover of fish's feed and the area of open soil can be taken into account.

If this status cannot be improved, many people would not have place for jogging, swimming, boating, or other recreation activities. As mentioned, this is the aesthetic landscape of the town as well as the considerable income from tourism services which has costs and benefits.

The install of two aerators has temporally affected water quality, however rotation of aerators is not so even, namely average rotation round of aerator I 6,5 r/min, aerator II 5,6 r/min. Sometimes, it did not work because of too low windspeed. Some paremeters measured in aerator II also showed its low efficiency. Therefore, other complementary energy is needed for properly working of aerator II.

Participatory skills are always necessary for successful lake management. Many case studies showed that the cooporation of indigenous people and local authorities is much more successful, because implementing the regulation is costly and labor consuming. For example, planning for fishing zone and fishing methods or fish culture areas are good practices from Phewa Lake, Pokhara, Nepal (Tek B Gurung et al., 2005). Other reasons for engagement of local people are that people want to know the results of their efforts, they may feel proud of their work, and prefer evaluate their own than being forced (Ramsar Convention Secretariat, 2007).

IV. Conclusion

The TSI results show that water quality of the lake is still eutrophicated. There are slight differences in spatial variability of parameters. The changes in parameters through years in water quality can clearly show the improvement of water quality and positive effect of two aerators. However, these indicators can partly show the ecological state of the lake. According to WFD lake condition can be completely assessed by combining other indicators such as macrophytes, phytoplankton, zoobenthos and so on.

In order to mitigate this problem, the local authority and residents need to actively participate in controlling nutrient input (point sources and non-point sources) and protecting the lake. Planting trees along the bank is also a good practice to reduce nutrient from rain water runoff and bank erosion. Nevertheless, public awareness and law enforcement need to be enhanced because this lake is very important for community in recreation, aesthetic services, human health and other ecological function.

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Appendix

Annex 1. pH measurement

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
0	8.1	8.1	8.1	8.0	8.1	8.1	8.1	8.0	8.0
1	8.1	8.1	8.1	8.0	8.1	8.0		7.8	8.0
2	8.0	8.1	8.2	8.0	8.1	8.1		7.8	7.9
3	8.0	8.0	8.1	7.8		8.0			8.0
4	7.8	7.7	8.0	7.7		7.8			
5	7.6	7.6	7.7	7.6		7.6			
6	7.6	7.5	7.7	7.5					
7	7.5	7.5	7.6	7.5					
8	7.5	7.4	7.5	7.4					
9	7.5	7.4	7.5	7.4					
10	7.4	7.3	7.5	7.4					
11	7.4								
12	7.4								
13	7.3								
14	7.2								

Annex 2. Conductivity ((µS/cm)

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
0	629.3	633.3	631.7	631.6	632.5	632.0	634.0	643.0	632.0
1	630.5	632.8	630.3	631.8	631.0	634.0	633.0	641.0	631.0
2	630.5	633.0	635.7	634.2	632.0	631.0	633.0	643.0	631.0
3	643.7	639.8	644.3	648.6	639.0	640.0			642.0
4	665.5	666.5	653.0	666.0	665.5	658.0			
5	669.2	680.8	672.7	674.8	681.0	691.0			
6	677.8	679.0	678.3	679.4					
7	626.0	676.8	678.0	678.8					
8	624.0	675.3	675.7	676.4					
9	672.0	673.3	677.0	675.4					
10	672.3	672.0	674.3	676.6					
11	673.3								
12	675.0								
13	681.7								
14	700.7								

Annex 3. Temperature (^oC)

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
0	24.3	23.8	25.6	25.1	24.2	26.4	23.2	24.7	24.4
1	24.1	23.4	25.6	24.3	23.8	23.9	23.2	24.0	23.7
2	23.7	22.9	24.3	23.2	23.2	22.6	23.2	21.9	23.4

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
3	22.6	22.0	20.8	20.3	22.1	21.9			21.8
4	17.3	17.4	18.9	17.0	17.4	19.2			
5	13.4	13.2	16.3	13.7	12.9	12.1			
6	10.9	11.0	12.7	11.1					
7	9.5	9.6	10.1	9.8					
8	8.5	8.6	8.7	8.7					
9	7.5	7.6	8.9	7.9					
10	6.9	7.0	7.6	7.1					
11	6.5								
12	6.2								
13	6.0								
14	5.8								
14.6	2.8								

Annex 4. DO (mg/l)

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
0	29.49	10.47	11.28	10.91	10.58	10.61	10.03	9.51	10.72
1	29.66	10.41	11.49	10.82	10.57	9.98	9.97	3.46	10.62
2	29.54	9.94	10.81	10.31	10.39	9.55	9.55	8.40	10.45
3	27.10	8.08	8.42	6.16	8.33	7.03			6.98
4	4.21	0.98	5.25	1.53	0.92	1.67			
5	0.22	0.22	3.25	0.24	0.24	0.21			
6	0.34	0.14	0.56	0.13					
7	0.42	0.23	0.51	0.15					
8	0.27	0.12	0.47	0.12					
9	0.29	0.11	0.17	0.29					
10	0.24	0.11	0.11	0.27					
11	0.26								
12	0.27								
13	0.22								
14	0.09								

Annex 5. TDS (mg/L)

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
0	0.409	0.412	0.410	0.410	0.411	0.410	0.412	0.418	0.411
1	0.410	0.412	0.410	0.411	0.411	0.412	0.411	0.417	0.410
2	0.410	0.412	0.413	0.412	0.411	0.411	0.411	0.418	0.410
3	0.415	0.416	0.419	0.422	0.420	0.416			0.417
4	0.432	0.433	0.424	0.433	0.432	0.428			

Depth (m)	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Dock near swimming pool	Inflow	Outflow
5	0.442	0.443	0.437	0.440	0.443	0.448			
6	0.439	0.442	0.442	0.442					
7	0.439	0.432	0.442	0.441					
8	0.438	0.439	0.439	0.438					
9	0.437	0.438	0.439	0.439					
10	0.437	0.437	0.438	0.440					
11	0.438								
12	0.439								
13	0.443								
14	0.456								
14.6	0.466								

Annex 6. Secchi disc (m)

Depth	Aerator 1	Middle 1a	Middle 1b	Aerator 2	Swimming pool west	East beach	Inflow	200m near inflow	Outflow
(m)	1.53	1.73	1.47	1.47	1.43	1.50	2.00	1.80	1.70