SPATIAL MONITORING OF THE FOURTH SECTOR OF LAKE PALIC

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Summary: *This paper present an overview of a one-day measuring campaign implemented along the shoreline of the fourth sector of Lake Palic. The measurements aimed to provide a more comprehensive understanding of spatial changes in water quality. Four water quality parameters (electric conductivity, water temperature, dissolved oxygen, pH) were measured on 18 locations, resulting in 72 measurements. The data set was subject to both fundamental analysis and cluster analysis. The imployed methodology gave results that can identify two, possibly three, groups of sampling locations. The first group represents the shoreline adjacent to agricultural lands, while the second group is comprised of sites in the vicinity of zones with considerable anthropogenic pressure. The (optional) third group could be put in either of the first categories, and it can be considered as locations with minor anthropogenic pressure.*

Keywords: *measurements, water quality, cluster analysis, Lake Palic*

1. INTRODUCTION

This paper describes further research regarding the spatial water quality distribution along the shoreline of Lake Palic’s fourth sector (Autonomous Province of Vojvodina, Republic of Serbia). Namely, after the previously conducted all-inclusive analysis of the existing monthly water quality data [1, 2, 3], the Authors concluded additional research could prove beneficial. Proper understanding of the gathered data highly depends on the quality of the measurements. Therefore it is essential to ensure the quality and quantity of the data are sufficient [4]. An additional question resulting from our earlier research was regarding the scale of these systematic measurements, should they be more frequent in space, time, or both. To answer this question, we implemented two separate measuring campaigns, one focusing on the temporal changes by daily monitoring of the selected water quality parameters. The other measuring campaign aimed to determine the water quality's spatial variations by conducting a set of measurements around the lake within a short time

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interval. Providing measurements distributed around the lake could provide additional information regarding the necessity of measuring at multiple locations. Namely, the ongoing measurements conducted on regular occasions within the fourth sector of Lake Palic are implemented at two, sometimes three locations. However, selecting a particular location for systematic sampling during an extensive period can give unrealistic results since not all parts of the lake are subject to the same external influences.

This paper presents the measurements, the analysis that these measurements were subject to, and the conclusions regarding the differences and/or grouping of similar sampling locations around the shoreline of Lake Palic's fourth sector.

2. MEASUREMENTS

The measurements were organized around the fourth sector of Lake Palic. The goal was to cover the lake's shore evenly as possible. One major issue regarding the measurements was the accessibility of different locations since the lake's sector covers a large area with various uses. The sampling locations are presented in Fig. 1.

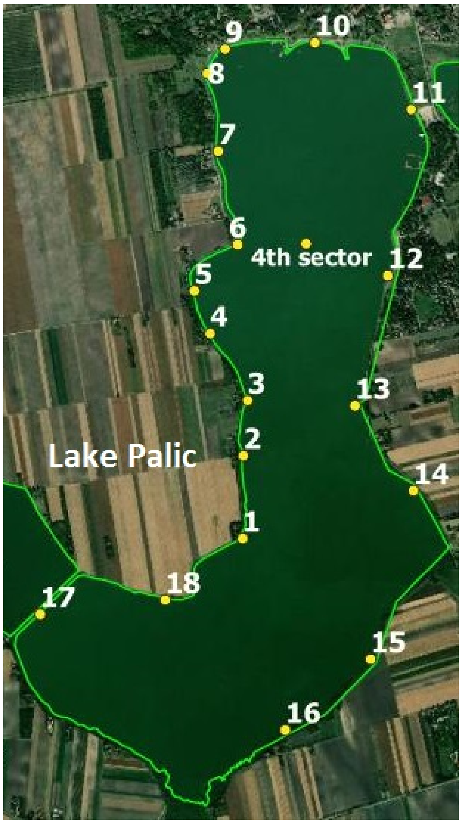


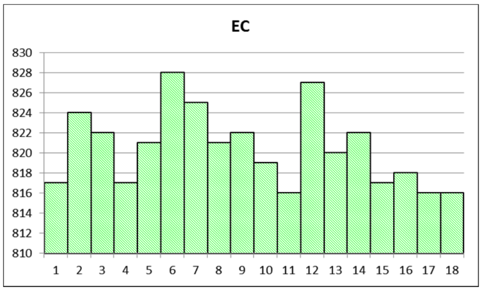
Figure 1. Lake Palic – Sampling locations

There was a total of 18 sampling locations that included water next to agricultural land (points 18, 1, 2, 3, 4, 5, 6, 13, 14, 15, 16), the area intended as touristic locations (sites 7 to 12), places visited mainly by fishermen (17). Although this is the general distribution of the measuring locations, it should be noted that some of these locations have mixed uses, making the impact of the land use on the water quality harder to determine. Nevertheless, it is expected to notice some level of differentiation between the distinguished areas.

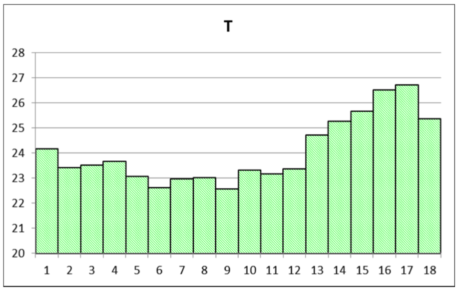
The implemented measurements were carried out during one day to make sure the gathered dataset be as homogenous as possible. The selected parameters included only four water quality indicators, temperature (measured and presented in ˚C), dissolved oxygen (in mg/L), electric conductivity (measured and presented in μS/cm), and pH (-) value. S suspended sediment contents were omitted from the measuring campaign since it requires laboratory analysis of the sample, making the process much longer.

3. RESULTS

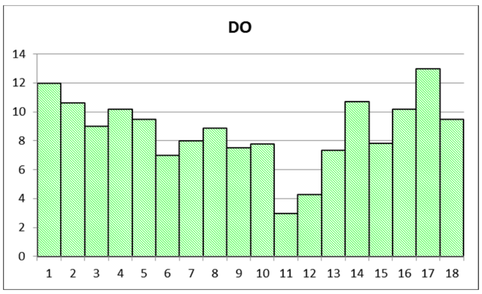
Figure 2 displays the results of water quality measurements around the fourth sector of Lake Palic in the form of histograms.



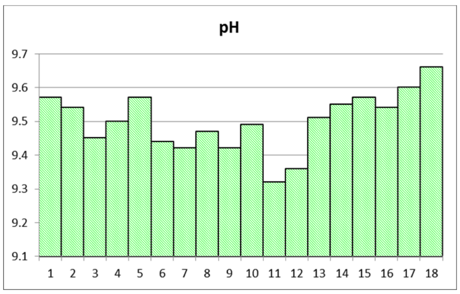
(a)



(b)



(b)
(c)



(d)

Figure 2. Histogram of the measurements around the lake

Careful evaluation of the attained data suggests that some changes in water quality are noticeable. For example, Fig. 2(a) presents the electric conductivity at the monitored locations, where we can see that some changes do appear. Namely, points 15, 16, 17, 18, and 1 display similar values of conductivity. By analyzing the locations, one can see all of these points fall into the category of sites not generally visited by people. All these points are near agricultural fields, except point 7 that is near the entrance into the fourth sector of the lake. Another significant exception is at point 11, where the value is closer to those next to agricultural fields than to the touristic area. This can potentially be explained as a result of the point being next to the lake's outflow, making this area subject to more water flow than the rest of the water body. The remaining points show increased electric conductivity values that seem to peak around the lake's most-populated shorelines.

Nevertheless, before making definite conclusions, the remaining parameters need to be evaluated to confirm or dispute this hypothesis. Figure 2(b) presents the changes in water temperature around the lake. The histogram seems relatively uniform with an overall increasing tendency that is most probably due to the measurements' duration. Since the sampling was started in the morning and continued until the afternoon when the air temperature increases, the systematically increased temperature values are probably the aftereffect of increased air temperatures. Figure 2(c) shows the distribution of dissolved oxygen around the fourth sector of the lake. An obvious occurrence standing out is the reduced value of dissolved oxygen at points 11 and 12. The first of these two is the outflow, which is to be expected. Another location with reduced oxygen values is identified at site 15. Regarding the pH values (Fig. 2(d)), they also show significant differences at points 11 and 12. In contrast, the rest of the results tend to have higher values near agricultural lands than those near populated areas.

A more profound understanding of the values may be provided by the representation given in Fig 3. This type of depiction is more suitable to help establish if a particular outlier is a result of a singular increased value or is it a part of a more general increase in the monitored parameter’s values. Therefore, Fig. 3(a) shows the electric conductivity where we can confirm the previously noted occurrence. The values increase towards the lake's touristic part, which is highly populated and subject to increased anthropogenic pressure. Electric conductivity remains at lower levels near the lands that are not populated (i.e., agricultural lands).

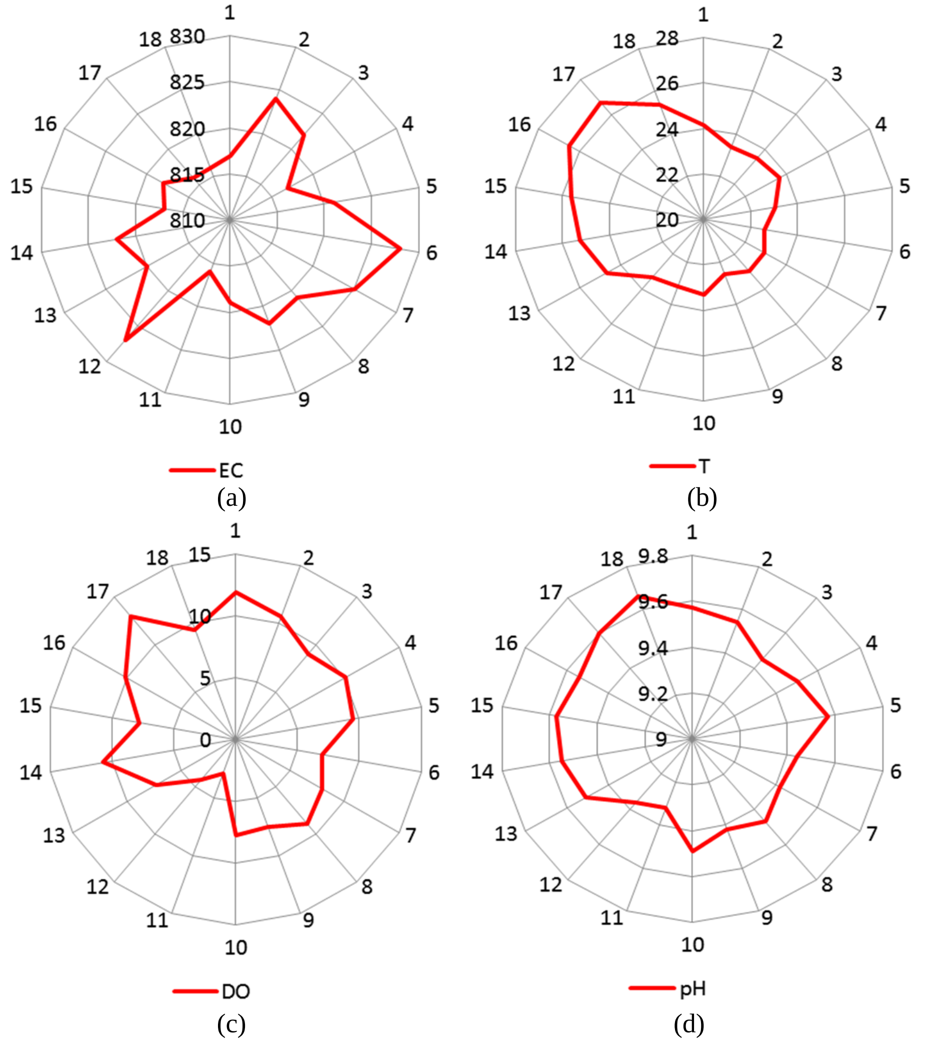


Figure 3. Radar chart of the measurements around the lake

Figure 3(b) also confirms the previous conclusions made by inspecting boxplots. The temperature changes around the lake are uniform with an increasing tendency from point 1 towards point 18, most probably due to the time of the day when the samples were taken. However, it may also be the result of increased mixing of the water in the populated area. Regarding the dissolved oxygen (Fig. 2(c)), there are no definite conclusions to be made other than points 11, 12, 15, and 18 standing out with notably smaller values. The pH values (Fig. 2(d)) seem to have a general divergence between the values near the agricultural lands and tose near the locations with higher anthropogenic pressures.
Figure 4 provides the box plot of electric conductivity with labeled values of the mean (larger square in the box), median (line in the box), outliners (whiskers), as well as the

measured values (smaller squares). Evaluating the results in this form helps us see the spread of the measurements. The box itself depicts the interquartile range (IRQ), i.e., the range between the 25th and 75th percentile.

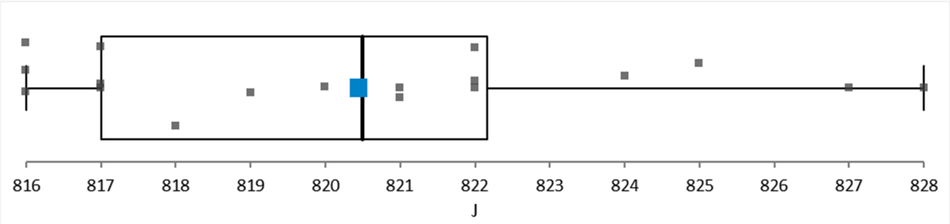


Figure 4. Box plot of electric conductivity (EC) around the lake

Figure 5 shows the box plot for the measured temperatures using the same labeling as previously. Unlike in the case of the electric conductivity, where the median and mean had very similar values, here, one can note a significant discrepancy between these two values. On the other hand, temperature values also seem to have a notable spread of measured values. Figure 6 presents the values of dissolved oxygen where most of the data seem to group within the box, just like in the case of pH values illustrated in Fig. 7. It is evident that dissolved oxygen values show the most dramatic dispersion, indicating that this particular water quality parameter is most vulnerable and most prone to dramatic changes due to external factors.

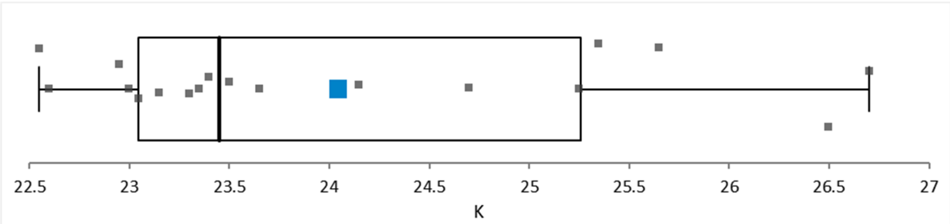


Figure 5. Box plot of temperature (T) around the lake

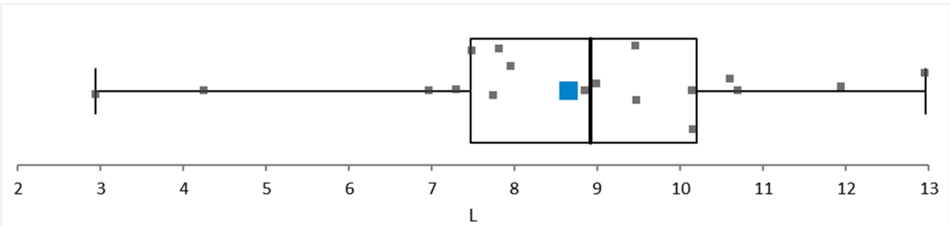


Figure 6. Box plot of dissolved oxygen (DO) around the lake

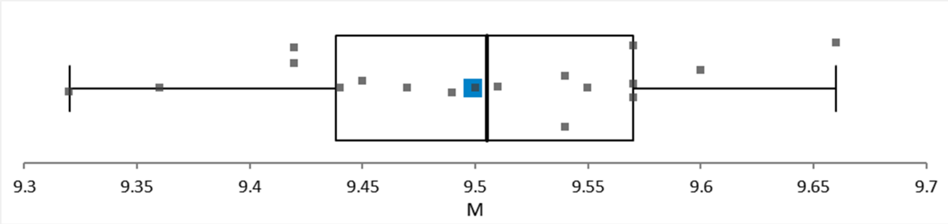


Figure 7. Box plot of pH around the lake

An elementary statistical analysis of the measured data is presented in Tab. 1, containing all basic information, the mean, standard deviation (SD), minimum, median, and maximum of the data set.

Table 1. Statistics for the measured data set

Variable	Mean	SD	Minimum	Median	Maximum
EC	820.4	3.8	816	820.5	828
T	24.044	1.319	22.55	23.450	26.70
DO	8.652	2.466	2.94	8.920	12.96
pH	9.499	0.087	9.32	9.505	9.66

Tables 2, 3, and 4 show the computed values of the correlation coefficients between the analyzed water quality parameters. Careful examination of the data suggests there is a potential to establish a fitted equation that would enable the computation of one parameter after measuring the other. Temperature measurements are easily implemented and do not require expensive equipment. Therefore temperature would be a reasonable candidate to be considered as a frequently monitored parameter. Another parameter that can be registered quickly and which doesn't require complicated analysis is the pH value. Consequently, the aim would be to establish a fitted equation that can provide expected electric conductivity values and/or dissolved oxygen through the measured values of temperature and pH value.

Table 2. Pearson's correlation coefficient

	EC	T	DO	pH	
EC	-	-0.571	-0.302	-0.469	Pearson's r
T	-0.571	-	0.497	0.659	Pearson's r
DO	-0.302	0.497	-	0.796	Pearson's r
pH	-0.469	0.659	0.796	-	Pearson's r

Table 3. Kendall's rank correlation coefficient

	EC	T	DO	pH	
EC	-	-0.453	-0.223	-0.461	Kendall's tau
T	-0.453	-	0.412	0.558	Kendall's tau
DO	-0.223	0.412	-	0.585	Kendall's tau
pH	-0.461	0.558	0.585	-	Kendall's tau

Table 4. Spearman's rank correlation coefficient

	EC	T	DO	pH	
EC	-	-0.592	-0.276	-0.515	Spearman's rs
T	-0.592	-	0.552	0.717	Spearman's rs
DO	-0.276	0.552	-	0.734	Spearman's rs
pH	-0.515	0.717	0.734	-	Spearman's rs

Further analysis of the data included implementing principal component analysis (PCA) to determine other potential correlations not visible by simple visual inspection of the data. Using the Analyse-it software package, we computed the principal components presented in Tab. 5. As can be concluded from the results, the first two components include 86.3% of the overall variance.

Table 5. Spearman's rank correlation coefficient

Component	Variance	Proportion	Cumulative proportion
1	2.668	0.667	0.667
2	0.785	0.196	0.863
3	0.377	0.094	0.958
4	0.170	0.042	1.000

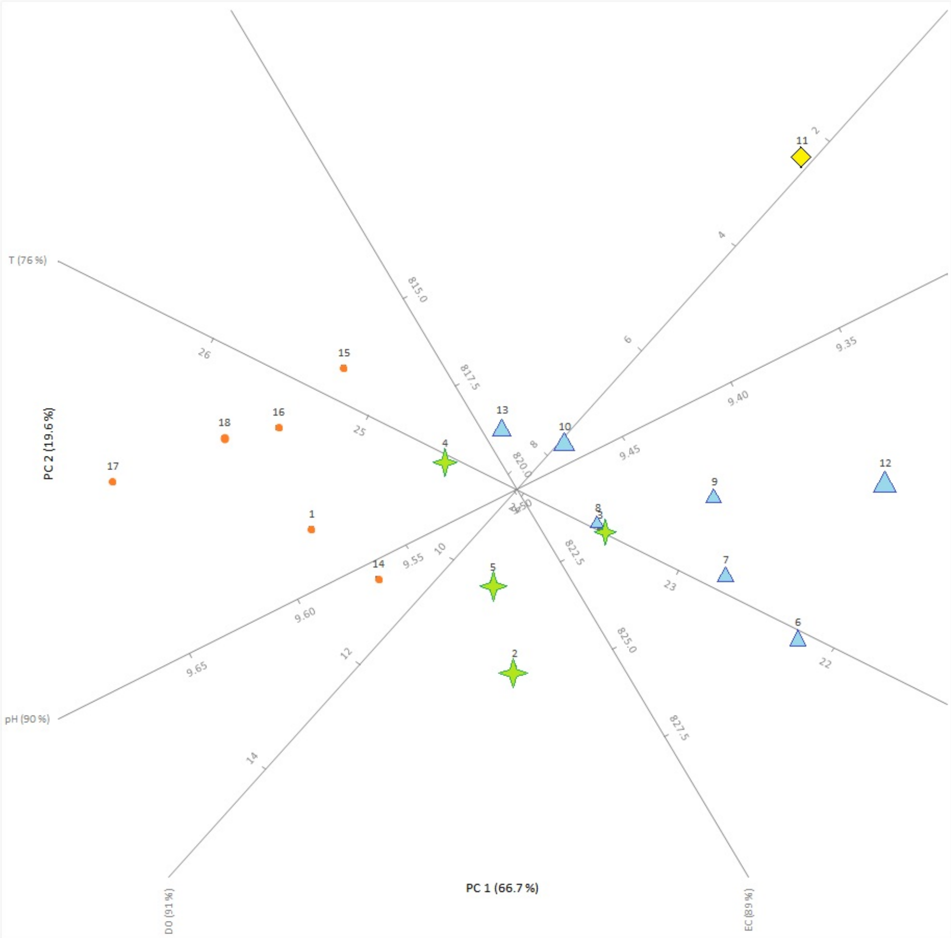


Figure 8. Biplot – principal component analysis

Figure 8 shows the measured data projected into a new 2-D coordinate system, defined by the first two principal components. This type of presentation of results lets us identify possible clustering that couldn't be noticed otherwise. For example, there seem to be three or four identifiable groups of data. Points 1, 14, 15, 16, 17, 18 make the first group and are marked as circles on the figure. If compared to the notations from Fig. 1 (i.e., when sampling locations are identified on the presented map), one can see that these points represent the lake's shoreline adjacent to agricultural lands. The second category includes points 6, 7, 8, 9, 10, 12, and 13 (labeled as triangles on Fig. 8) that fall into the populated area around the lake (i.e., shoreline with considerable anthropogenic pressure). Another separate category includes point 11 that seems to deviate from all other locations and can be considered an outlier. The fourth group is not a completely identifiable category since these sites show characteristics that could suggest they could be included in either of the first two groups. These are points 2, 3, 4, and 5, and they cover the shoreline that can't be considered a typical populated area, but there are individual houses there and even small rentals. These homes are small individual houses spread out on a large piece of land. This may explain the noted grouping of these points in between the two more easily definable categories.

4. CONCLUSION

A one-day measuring campaign was conducted around the entire shoreline of Lake Palic's fourth sector (Autonomous Province of Vojvodina, Republic of Serbia). Four water quality parameters (electric conductivity, water temperature, dissolved oxygen, pH) were measured on 18 locations, resulting in 72 measurements.

The gathered data set was subject to both basic analyses, including the construction of histograms, radar charts, box plots, computation of correlation coefficients, and cluster analysis relying on principal component analysis. The initial investigation suggested that although there are no drastic differences in the measured water quality parameters, certain locations can be identified to have water quality parameters that differ from those of the lake's shoreline. This observation was supported by the histograms and the radar chart, while the box plots identified a considerable difference between the dissolved oxygen’s mean value and the median.

Cluster analysis using principal components reduced the data set's dimensionality to just two dimensions while keeping 86.3% of the original data's variance. By plotting the data into a new coordinate system defined by the first two principal components, two, possibly three groups could be identified. The first group represents the shoreline adjacent to agricultural lands, while the second group is comprised of sampling locations in the vicinity of zones with considerable anthropogenic pressure. The (optional) third group could be put in either of the first categories, and it can be considered as locations with minor anthropogenic pressure.

In conclusion, measuring only basic water quality parameters around the shoreline of the fourth sector of Lake Palic gave us the opportunity to process this data, both elemental analysis and cluster analysis that relies on principal components. This means that zones of shorelines with considerable anthropogenic pressure could be easily identified, thus giving a new method in formulating possible guidelines for future monitoring systems and remediation efforts for the fourth sector of Lake Palic.

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ПРОСТОРНИ МОНИТОРИНГ ЧЕТВРТОГ СЕКТОРА ЈЕЗЕРА ПАЛИЋ

Резиме: *У раду је представљена кампања мерења у трајању од једног дана дуж обале четвртог сектора језера Палић. Сврха организованих мерења је била да се обезбеди боље разумевање просторних промена квалитета воде. Мерена су четири параметра квалитета воде (електрична проводљивост, температура воде, растворени кисеоник, pH вредност) на 18 локација, што је резултовало са укупно 72 измерена податка. Формирани сет података је подвргнут елементарној анализи и анализи груписања података. Примењена методологија је дала резултате помоћу којих је могуће идентификовати две, а можда и три групе места узорковања. Прва група обухвата потез обале у непосредној близини пољопривредних земљишта, док друга група обухвата локације у непосредној близини људских активности. Трећа (опциона) група обухвата локације узорковања које се могу сврстати у било коју од прве две групе. Ове локације се могу окарактерисати као места са умереном људском активношћу.*

Кључне речи: *мерења,квалитет воде, анализа груписања података, језеро Палић*