A System for Studying the Living Environment of Freshwater Living Fish

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***Abstract*— When breeding live fish, such as carp, crucian carp, grass carp and storing them in intermediate warehouses, problems with the quality of the environment sometimes arise. In this case, in order to reduce mortality, it is necessary to take measures related to ensuring a quality environment. In the work, a mobile system for measuring basic indicators of water pH, dissolved oxygen, temperature is proposed. With the system was made measurements in two rivers and one dam in which fish are grown. It was found that at this stage, the environment conditions are within normal limits.**

***Keywords*— freshwater fish, a mobile system for measuring basic indicators of water, main indicators of water, quality environment**

I. INTRODUCTION

Freshwater fish such as carp, grass carp, catfish, pike, walleye are bred freely in rivers, lakes, dams and fishponds. In the rivers, the indicators of the water environment are not monitored, because the constantly flowing water is relied on to maintain the normal conditions for the life of the fish. They are only checked periodically by the state offices responsible for them. In fishponds, it is desirable to constantly monitor the state of the environment, because a large amount of fish is grown in a small volume, [1]. In the case of dams and lakes, because they are usually of larger volumes, measurements are made less often to determine the quality of life of the environment, or they are not made at all. Usually react intuitively, according to the behavior of the fish. Exceptions are small lakes used as fishponds [2]. In addition to these reservoirs, live fish are transported by vehicles in tanks to intermediate pools (storage). In them, it is stored for short periods of about a week before being transacted or delivered to customers [3]. In these environments, the state of the environment should also be monitored, because there the fish are collected in small volumes, in which the main indicators of the environment, such as dissolved oxygen (O_2), carbon dioxide (CO_2), water temperature (T° C), especially during hot summer days. The change in indicators is also related to the amount and activity of fish in the reservoir. Therefore, various methods and models have been created, such as R-CNN [4] and YOLOv5-CNN to determine the amount of fish in turbid waters or dark waters [5]. When it is established that due to changes in the environment, the fish population is decreasing, new technologies are applied to minimize their impact [6]. In this regard, it is necessary to periodically control the environment and maintain it within normal limits by adding oxygen, fresh water and even ice. Another environment where it is important to maintain water quality is the fish breeding tank. In this regard, the use of Smart IoT based monitoring system for fish breeding is proposed [7]. This Jade Smart 1.0 system measures and visualizes in real time the values of three main indicators: acidity (pH), water temperature and water turbidity. This avoids the need to periodically manually check the environment. A disadvantage of the system is that it does not measure the values of dissolved oxygen, carbon dioxide and ammonia, which are important indicators during warm and hot days.

The development of technologies allows the use of mobile systems for rapid control of the state of the aquatic environment in which the live fish is located so that it can be maintained within normal limits. Such systems are mainly built to measure water temperature, pH and turbidity [8]. This can be done in smaller reservoirs, such as fishponds, hatcheries, intermediate storage and transport tanks located in vehicles, through systems that continuously measure the main indicators of the environment and visualize them, informing the people who raise the fish, [1], [9]. In other water environments, rivers, lakes and reservoirs, where volumes are large, it is more appropriate to periodically make measurements by taking samples. This can be done through dedicated water sampling devices and measurement systems that can be fixed in laboratories or mobile. In the present work, the use of a mobile system for measuring the main parameters of the water in which live fish are grown is proposed.

II. DESCRIPTION OF THE MAIN INDICATORS FOR WATER MEASUREMENT

The study of the behavior of fish in freshwater basins is related both to their rearing for fishing and to determining their migration and behavior. In recent decades, hydrotechnical facilities have been built along major navigable rivers, which block the path of fish and impede their migration, [10], [11]. The influence is strong during the daylight hours, when 45 % of fish slow down their movement due to obstructions in their path and this affects on their behavior [12]. In addition, the water temperature is also a serious factor, which determines when the fish will start their migration related to reproduction, [13]. In recent decades, there have been major climate changes that affect the environment in which fish live and breed. These changes force fish to adapt to them [14]. When the change in the environment in which fish live is not related to human intervention, such as reducing or increasing the water level in lakes, it does not deteriorate the habitat conditions of fish [15].

In the Republic of Bulgaria, the Program "2021BG14MFPR001" was adopted for the period 2021-2027, in which it is indicated that efforts are directed to introducing innovations in fish production and reducing water pollution, by introducing effective and adequate systems and carrying out of monitoring research, including the use of artificial intelligence [16]. In connection with the implementation of the plan, cooperation with scientific organizations to carry out periodic research is envisaged. The results of the research are scheduled to be published on the website of the Executive agency for fisheries and aquaculture, [17]. Similar studies related to the quality of the environment in which the fish live are also carried out in other countries. What is common in all studies is that systems are created to monitor basic indicators of water, which differ in complexity, number of measured indicators, accuracy of the devices and cost. Some of them, in addition to measuring, are also used to predict changes in the environment over time. For fish farms or for aquariums, in which various preparations are used to maintain a quality environment, the manufacturing companies have provided simplified methods for manually determining the quantities of the investigated indicators, which are suspected to be not within the norms. These are pH, Ammonium (NH_4/NH_3), Nitrite (NO_2), Nitrate (NO_3), Phosphat (PO_4), Iron (Fe), Copper (Cu), Chlor (Cl), Carbonate hardness (KH), [18]. Limit values and acceptable values for the environment are specified for each of the measured indicators. O_2 values should be above 6 mg/l, CO_2 – below 20-25 mg/l, pH – 8-9, NH_4 – below 0.25 mg/l, NO_3 – below 20 mg/l, Cl < 0, 02 etc. Therefore, the indicators that are important to be measured initially are pH, water temperature and dissolved O_2. Additionally, measurement of NO_3, NH_4 and Cl and CO_2 is provided. The measurement will be done by sampling the water sources. In this regard, it is necessary to create a mobile measurement system in field conditions at a reasonable cost and acceptable accuracy.

III. Description of the Assesment Methodology

The measurement of the main indicators of the water in which live fish live or are stored is intended to be carried out with a mobile autonomous measurement system. For this purpose, such a system was prepared, which consists of 1 - a controller for data collection, 2 - a container for placing the water samples and fixing the measuring probes, 3 - fixing stands for the measuring probes, 4 - a pH sensor, measuring from 0 - 14; 5 – temperature sensor, range from – 20 to 115 °C, accuracy: ±0.5 °C; 6 – dissolved oxygen sensor, measures from zero to 20 mg/L with an accuracy of ± 0.4 mg/L; 7 – sensor for measuring chlorides, measures from 1 to 35,000 mg/L; 8 – sensor for measuring nitrates, in the range from 1 to 100 mg/L; 9 – sensor for measuring ammonia, calibrated from 1 to 100 mg/L; and 10 – sensor for measuring carbon dioxide range 0 - 10 000 mg/L. The accuracy of the last 4 sensors is ±10%; 11 – bottles for storing the sensors, Fig.1.

Data processing for visualization is performed with the Logger Pro 3 software product [19].

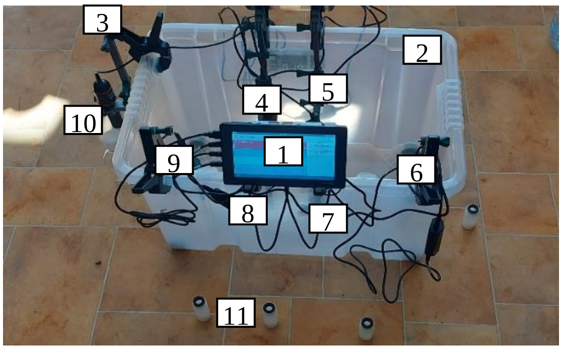


Fig. 1. General view of the mobile measurement system

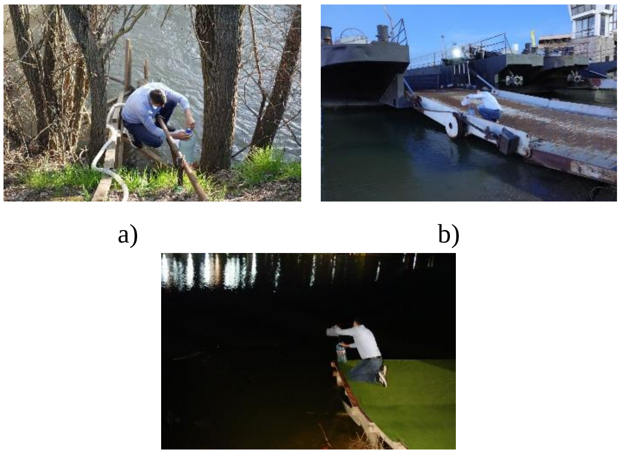
It is planned to take samples from three water sources: the "Rusenski Lom" river, which is 196.9 km long and flows into the "Danube" river, [20], the "Danube" river and the "Nikolovo" dam in the "Teketo" area to the village of Nikolovo, which is about 10 km from the city of Ruse. The measurement of the values of the main parameters of the water taken from the water zones is done immediately. Data are recorded in the memory of the LabQuest 3 device. Mathematical processing was performed with Origin v.9.8.

All sensors have a coupler to connect to an analog input. Therefore, three sensors are connected to the device in the three analog inputs. The data acquisition device also has two USB ports. Up to 4 analog sensors can be connected to each USB port through a suitable connector.

After the measurement, the next three sensors can be switched on to make a complete measurement. In this case, the measurement will be made with only the following three sensors: for temperature, dissolved oxygen and pH. This procedure is done for all water sources. The recorded data is then transferred to a computer and processed there using the Logger Pro 3 program.

IV. Experimental Research

The research was done over a period of one year from March 2023 to March 2024. Samples were taken from the three sources over an average of two months. The sampling order is shown for the last measurement in March 2024: first, samples were taken for measuring water from the river "Rusenski Lom" at 17:25 h, Fig.2a, then from the river "Danube" at 19:42 h, Fig.2b and finally at 20:31 h from the dam " Nikolovo", Fig. 2c. The water samples were taken on 29/03/2024. It is a warm and sunny day with an air temperature during the day of around 26°C. The data were then processed on a computer.



a) b)

c)

Fig. 2. Sampling of the three water sources

The collected data were transferred from labQuest 3 to the processing program Logger Pro 3. They are presented in TABLE I.

TABLE I. Data for T°C, pH and O_2

Logger Pro - Data fish Ruse 2024.cmbl*

No device connected.

	River Rusenski lom				River Danube				Dam Nikolovo			
	Times,sec.	T, °C	pH	O2	t	T, °C	pH	O2	t	T, °C	pH	O2
1	1	16,3	8,7	8,49	1	15,1	8,4	8,8	1	13,8	8,26	9,4
2	2	16,2	8,7	8,49	2	15,1	8,4	8,8	2	13,8	8,26	9,4
3	3	16	8,7	8,49	3	15	8,4	8,8	3	13,7	8,26	9,41
4	4	15,8	8,65	8,5	4	15	8,41	8,82	4	13,7	8,27	9,42
5	5	15,6	8,63	8,5	5	14,7	8,41	8,82	5	13,7	8,27	9,42
6	6	15,4	8,6	8,5	6	14,5	8,4	8,83	6	13,7	8,27	9,42
7	7	15,2	8,6	8,5	7	14,3	8,4	8,83	7	13,6	8,29	9,43
8	8	15	8,6	8,5	8	14,2	8,39	8,84	8	13,6	8,29	9,43
9	9	14,9	8,57	8,5	9	14	8,39	8,84	9	13,6	8,29	9,44
10	10	14,9	8,54	8,51	10	13,9	8,34	8,85	10	13,6	8,3	9,44

After the transfer, the data is visualized in Fig.6.

The amount of oxygen (O_2) in the water is directly related to temperature changes, and therefore the O_{2Lom} (1) for Rusenski Lom, $O_{2Danube}$ (2) for "Danube" and O_{2Lace} (3) for "Lake Nikolovo" plots against time are derived, as and constructed the comparative curves in fig.3.

The change in the amount of O_2 depending on the temperature for the three water sources "Rusenski lom" "Danube" and "Lake Nikolovo" is also clearly visible in the constructed comparative characteristic in fig.3. The biggest change is observed in "Lake Nikolovo", and the weakest change is found in "Rusenski lom". The reason for this behavior is a small amount of incoming water streams in "Lake Nikolovo", while at "Rusenski lom" the water is constantly mixed downstream and adds new water from small rock streams. The equations describing the change law confirm the established trends of "Rusenski lom" "Danube" and "Lake Nikolovo", with the highest change being found at "Lake Nikolovo" O_{2Lace} (3) and the lowest at "Rusenski lom" O_{2Lom} (1).

$$O_{2Lom} = - 4.541\times\ln(T) + 21.033 \quad (1)$$

$$O_{2Danube} = - 6.647\times\ln(T) + 26.723 \quad (2)$$

$$O_{2Lace} = - 65.13\times\ln(T) + 180.11 \quad (3)$$

where T is the temperature change in (°C).

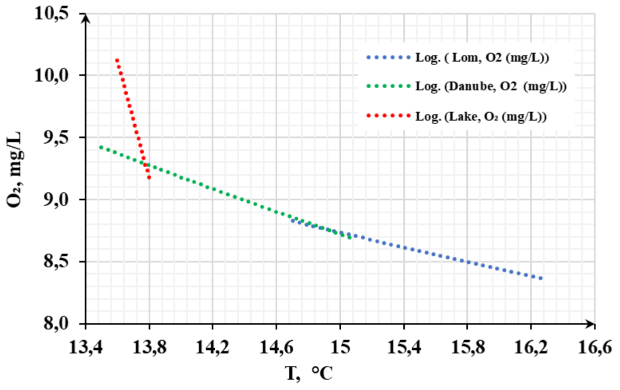


Fig. 3.Comparative characteristics of O2 change for "Rusenski lom", "Danube" and "Lake Nikolovo" depending on temperature (T, °C)

The conducted analytical and mathematical analysis shows that there is a relationship for the change in pH with an increase in temperature (T). The derived equations for the influence between pH and temperature (T) are presented in equations (4) for "Rusenski Lom", (5) for "Danube" and (6) for "Lake Nikolovo".

$$pH_{Lom} = 3.4214\times\ln(T) – 0.7883 \quad (4)$$

$$pH_{Danube} = 1.5506\ln(T) + 4.2245 \quad (5)$$

$$pH_{Lace} = - 30.32\times\ln(T) + 87.727 \quad (6)$$

where T is the temperature change in (°C).

From the representative equations, it can be seen that the "Rusenski Lom" and "Danube" equations have an increasing character with increasing temperature, which behavior is due to the overflow of warm flows from domestic sewage. The analytical equation of "Lake Nikolovo" has a decreasing character of pH with an increase in temperature, which decrease is due to the ongoing photosynthesis processes of the vegetation in the lake. Similar results are presented in [21].

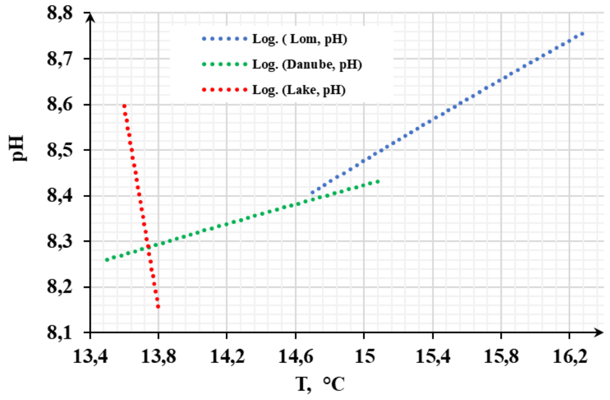


Fig. 4. Comparative characteristics of pH change for "Rusenski lom", "Danube" and "Lake Nikolovo" depending on temperature (T, °C)

The comparative characteristic of the relationship between O_2 and pH (fig. 5) shows that in the rivers "Rusensky Lom" and "Danube" with an increase in pH, the amount of dissolved oxygen (O_2) decreases. In "Lake Nikolovo" the tendency is that as the pH increases, the amount of dissolved oxygen in the water increases. This behavior proves once again that the vegetation in the lake processes thioglycol chemicals for small hair curling, releasing one of its gaseous components in the form of O_2. The mathematical equations describing the relationship between O_2 and pH for "Rusensky Lom", "Danube" and "Lake Nikolovo" are given as (7), (8) and (9) respectively. The result shows that in the rivers "Rusensky Lom", "Danube" as the pH increases, the amount of oxygen decreases. A sensitive change is established on "Rusensky Lom", with the turbidity being high, and on the river "Danube" it changes more smoothly. The reason for this is the volume of water per unit area.

$$O_{2Lom} = 6.4708\times X^2 – 111.8\times X + 491.36 \quad (7)$$

$$O_{2Danube} = 34.269\times X^2 – 575.31\times X + 2423.4 \quad (8)$$

$$O_{2Lace} = 1.8284\times X^2 – 28.731\times X + 121.96 \quad (9)$$

where: X is the change in pH.

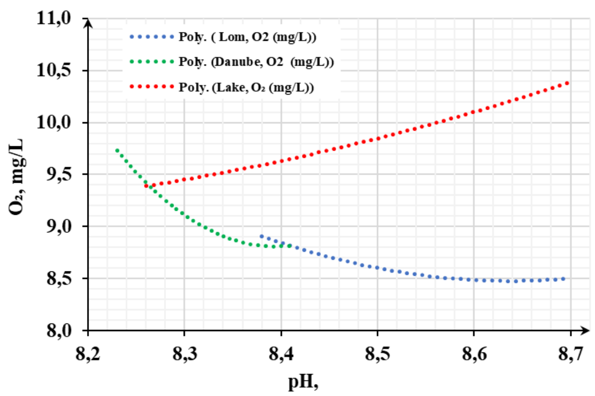


Fig. 5. Comparative characteristics of O2 change for "Rusenski lom", "Danube" and "Lake Nikolovo" depending on pH

From the conducted analysis, it is found that "Lake Nikolovo" maintains the living conditions of the fish through the biological diversity in the water and improves the living conditions by balancing the amount of oxygen through the water temperature. The input of increased pH is processed into energy supporting the increase of oxygen in the water.In rivers, the processing of high pH cannot be compensated for by the high velocity of the current. To reduce the pH is relied on the overflow of new clean spring water or by overflowing new natural river flows.

After processing in Logger Pro 3, it was found that on the same day, the „Rusenski lom” river had a pH of 8.40, which was 1.7 % higher than that of the “Danube” river, and at the same time „Rusenski lom” river had a pH of 8. 87 mg/L of dissolved oxygen, which is 6.9 % less than that in the “Danube” river. The low level of dissolved oxygen can be explained by the pollution of the river, because the sample was taken next to the industrial area of the city of Ruse before the confluence with the “Danube” river.

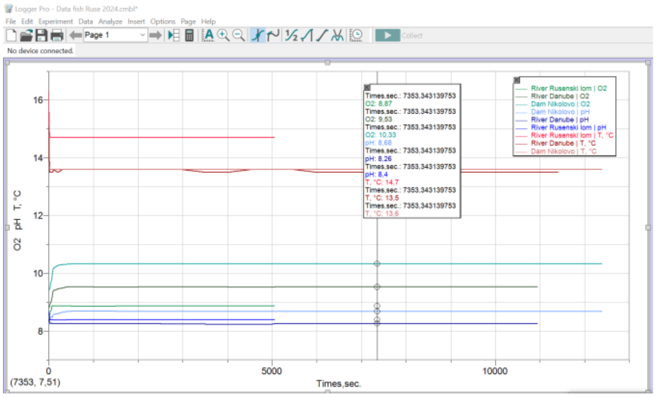


Fig. 6. Presentation of the data taken from the three water sources

The temperature of the water in the "Rusensky Lom" river is higher by about one degree Celsius, compared to the other water sources, because in the section from which the sample was taken, the water has a low velocity and a small flow rate. “Nikolovo” dam has the highest pH of 8.68 and the highest dissolved oxygen of 10.33. A number of fish species such as carp, whitefish, pike, grass carp, carp, walleye, catfish live in this dam and fishing is carried out. In general, the dam is kept in good condition as it also hosts boat races.

The final results are presented in TABLE II.

TABLE II. FINAL DATA FOR T°C, PH AND O_2

Water source	Time, h	T, °C	pH, units	O_2, mg/L
River “Rusenski lom”	1:40	14,7	8,40	8,87
River „Danube“	3:04	13,5	8,26	9,53
Dam “Nikolovo”	3:44	13,6	8,68	10,33

In general, the results of the research show that the three water basins have good indicators for the fish living in them. The results of the research are relevant not only to water body owners and control authorities, but also to citizens who are interested in the state of the environment and those who wish to learn to distinguish a favorable environment from an unfavorable one.

V. CONCLUSION

Presented is a mobile system suitable for rapid examination of basic indicators of water in natural and artificially created basins, which can simultaneously measure three indicators with the analog inputs and up to four indicators with one digital USB port in the presence of such a tip.

The results of the research carried out in the three basins - the river "Rusenski Lom", the river "Danube" and the dam "Nikolovo" show that the pH is over 8.26, the temperature is about 14ºC and O_2 is over 8.86 mg/L with values that allow the fish to live normally. In order to fully determine the quality of water, it is necessary to carry out a study to determine the concentration of all substances in the water, and these studies should be conducted periodically and the data obtained should be published on sites to which citizens have free access.

In order to improve the preparation of society in terms of protecting the purity of water in basins, it is appropriate to introduce into the educational process the prepared mobile system for measuring the values of basic indicators of water or another similar system. In this way, the citizens will have an idea of the appropriate values of the main indicators of the water in the basins and it will be possible to react in time in case of deviation from them.

An increase in temperature (T, °C) leads to a decrease in the amount of oxygen (O_2) in the water.

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