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Sensor system for in-situ monitoring the surface waters quality of the Veleka River, Strandzha Nature Park (Bulgaria)

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Abstract. Monitoring the environmental status along the Veleka River (Strandzha Mtn, Bulgaria) is an essential measure for avoiding the dangers of ecological catastrophes and for preserving the unique biological diversity in this region. A system for monitoring some of the main parameters of surface waters, soils and air, as well as the sunlight levels, has been designed and initially tested. For this purpose, an automatic, remote measuring station was developed, intended for installation on the shore, near the riverbed. It has been designed not only for collecting and archiving information about the physico-chemical status of the river, but also periodically sends the data to a communication server. The developed system of several automatic measuring stations will enable us not only to analyze the current status, but also to generate an early warning in case of danger health ecosystem decline.

Key words: protected ecosystems, water, air, soil quality, monitoring station.

Introduction

The Veleka River is a picturesque river, rising from the Demirkapu Peak in the Turkish part of Strandzha Mtn. About 3 km north of the village of Çaalayak (Turkey), it reaches Bulgaria, and along a stretch of about 2 km serves as a border between the two countries. The total length of the river is 145 km, 125 of which are located in the Bulgarian territory. The Veleka River passes through the heart of Strandzha Nature Park, the largest protected area in Bulgaria. It flows into the Black Sea near the village of Sinemorets.

Due to the unique features of the Veleka River surroundings, two protected places have been declared along its course - Veleka Protected Place and Veleka River Outfall.

The first one is situated into the middle stream of the river and aims to preserve the unique canyon of the Veleka River with its numerous meanders, as well as the old oak-beech forests which host many endangered birds and mammals (Petrova et al., 2024). The Veleka River Outfall Protected Place is situated at the lower part of its catchment basin and its outflow, where many protected plants and animals can be seen. This is the place where one of the biggest migratory routes of birds (Via Pontica) passes over the Black Sea coast (Petrova et al., 2024).

The Veleka River is one of the last regions in central and eastern Europe practically unaffected by human economic activity (Vassilev et al., 2013). In Aerts et al. (2018), the mechanisms and evidence for the positive effects on human health of biodiversity are reported. Therefore, it is extremely important to preserve the biological diversity in this pristine natural environment.

Our fields surveys previously showed that the Veleka River Outfall was the most exploited by tourists' territory of the Strandzha Nature Park in 2023 (Petrova et al., 2024) and also in the present 2024. That is why, we aim to develop an automatic sensor system for monitoring of the surface waters quality (physico-chemical status) of the Veleka River, which is intended to be installed on the shore, near the riverbed, and periodically will forward the data to a communication server.

Materials and Methods

Study area

In order to establish the critical points in relation to the anthropogenic impacts, 7 monitoring locations were selected along the Veleka River (Fig. 1).

A short description and their geographic coordinates are presented in Table 1.

These points were chosen to monitor the ecological status of the entire river along its whole length, with special attention paid to the lower part, including the outfall, where three monitoring locations were selected. Due to river flooding and the inability to access location 2, the location 2A was additionally selected to replace it (Fig. 2).

In addition, the monitoring locations were chosen so to be near settlements in order to access them by car. The proximity to populated areas was important criteria not only for the anthropogenic impact assessment, but also to allow us to provide a reliable communication link to transmit the measurement information from the sites to the system's communication server.

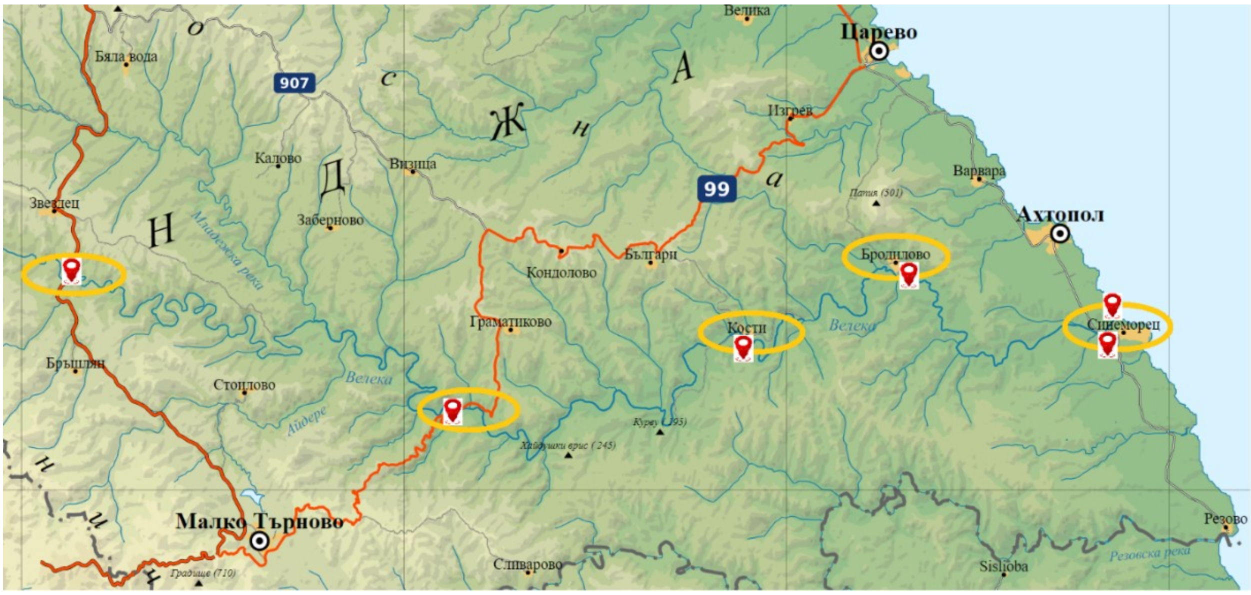

Fig. 1. Map of the monitoring locations.

Table 1. The Geographic coordinates of the monitoring locations.

Point number	Description	Location
Point 1	Outfall (before observation tower)	N 42° 03,798 E 27° 58,113
Point 2	After the bridge of the village of Sinemorets(in the direction from the mouth upwards)	N 42° 03,665 E 27° 57,679
Point 2A	Pier for motor boats next to the bridge of the village of Sinemorets	
Point 3	Rope bridge near the village of Brodilovo	N 42° 04,892 E 27° 51,618
Point 4	Rope bridge near the village of Kosti	N 42° 03,364 E 27° 46,884
Point 5	Bridge in Kachul area (near the village of Gramatikovo)	N 42° 01,673 E 27° 37,315
Point 6	Bridge in the Kovach area (near the village of Zvezdetz)	N 42° 04,885 E 27° 25,869

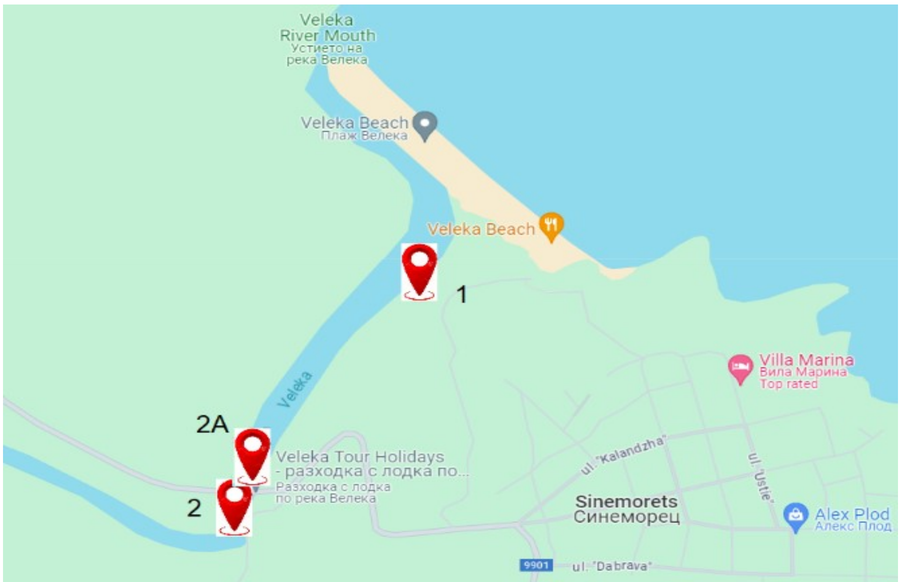

Fig. 2. The monitoring locations along near the river mouth

Structure of the Monitoring System

A. Measurement section

Some of the basic requirements for continuous surface water monitoring stations under EPA (2016) are to:

- Provide information to facilitate protection of the public water supply for all intended uses;
- Observe long-term trends in source water quality and prepare for future challenges or regulations;
- Detect and respond to contamination incidents;
- Optimize treatment processes to improve finished water quality and reduce costs;
- Develop information that supports regulatory compliance;
- Investigate and identify pollution sources and potentially responsible parties;
- Detect possible sources of contaminants and predict future possibilities which may be avoided.

Since the collected data will be used not only to analyze the river's pulsating condition, but also to generate online warnings when trigger situations occur, it is necessary to apply the techniques of frequent water quality determination. For example, in Rode et al. (2016) similar technics are used in the UK as an early warning tool for pollution incidents and subsequent investigation. The measured values include temperature, pH, conductivity, turbidity, dissolved oxygen, ammonium and chlorophyll concentrations, monitored at hourly intervals. Importantly, this data is made available to the academic community. Research organizations such as UKCEH and other UK universities are also deploying phosphorus auto-analyzers and nitrate probes to capture hourly nutrient concentrations. Full descriptions of typical monitoring station set-ups, telemetry and instrumentation can be found elsewhere (Rode et al., 2016).

There are several options for mounting the probe equipment for monitoring the surface water parameters, namely (Bowes et al., 2016):

- crab discovered on shore;
- waterfront cabin;
- cabin in the water, on a foundation;
- floating platform (PT, 2024).

The first method only applies to water treatment plants. The foundation of the station towards the bottom of the river leads to adverse ecological consequences and is inadmissible in our case.

The floating platform is suitable for use in cases where it is necessary to carry out an operational measurement in a place not equipped with a stationary station. It does not allow possibility to use directional antennas for the HF data transfer equipment.

Based on these considerations, we chose the option with a waterfront cabin (see Fig. 3).

In this way, the issues with the security of the remote equipment, with the power supply (it is possible to orient the photovoltaic panel to the south), with the non-constant water level (an internal measuring tank is used) are easily solved. Mounted in this way, the station also enables the installation of additional sensors to control sunlight and air quality. The sensor selection for water quality monitoring is presented in Table 2.

Within the framework of the project, an automatic measuring station was developed for determining the surface water quality. It can be additionally equipped with the means of measuring the quality of air, soil and the solar irradiation components. The structural diagram of the measuring station is shown in Fig. 3.

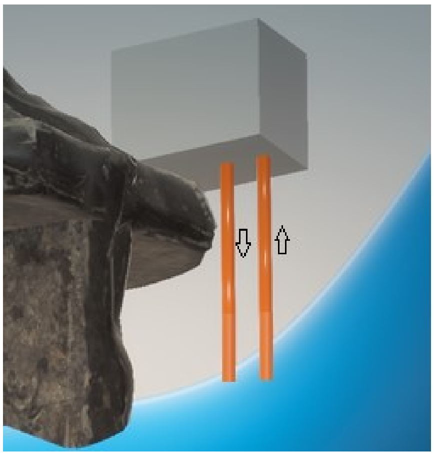

Fig. 3. Mounting the waterfront cabin on the coast.

The sensors listed in Table 2 are mounted in a common housing, together with a motorized brush for their cleaning (see Fig. 4). The entire hull is immersed in a specially designed test tank with a controlled filling level independent of the water level in the river.

After the measurement, the water from the reservoir is released back into the river immediately before the next measurement. The sensor modules should not be left dry because they get damaged.

Table 2. The Sensor for Water Quality Monitoring Types

No	Sensor	Range	Accuracy	Resolution
1	**Optical Dissolved Oxygen Probe**	0-20mg/L or 0-200%	±0.3mg/L	0.01mg/L
2	**A four-electrode conductivity sensor**	1uS/cm-200mS/cm 1uS/cm-100mS/cm	1% FS	0-1000uS/cm: 0.1uS/cm; 1mS/cm-100mS/cm: 0.1mS/cm
3	**Chlorophyll sensor**	0~400 ug/L or 0~100RFU	-	0.1 µg/L or 0.1% RFU
4	**Digital pH sensor**	0-14pH	±0.1pH	0.01
5	**Ammonia nitrogen sensor**	0~1000mg/L	±10%	0.1mg/L
6	**Oil in water sensor**	0-20ppm or 0-50ppm	0.01	0.1ppm
7	**Nitrate sensor**	0~1000mg/L	±5%	0.1mg/L

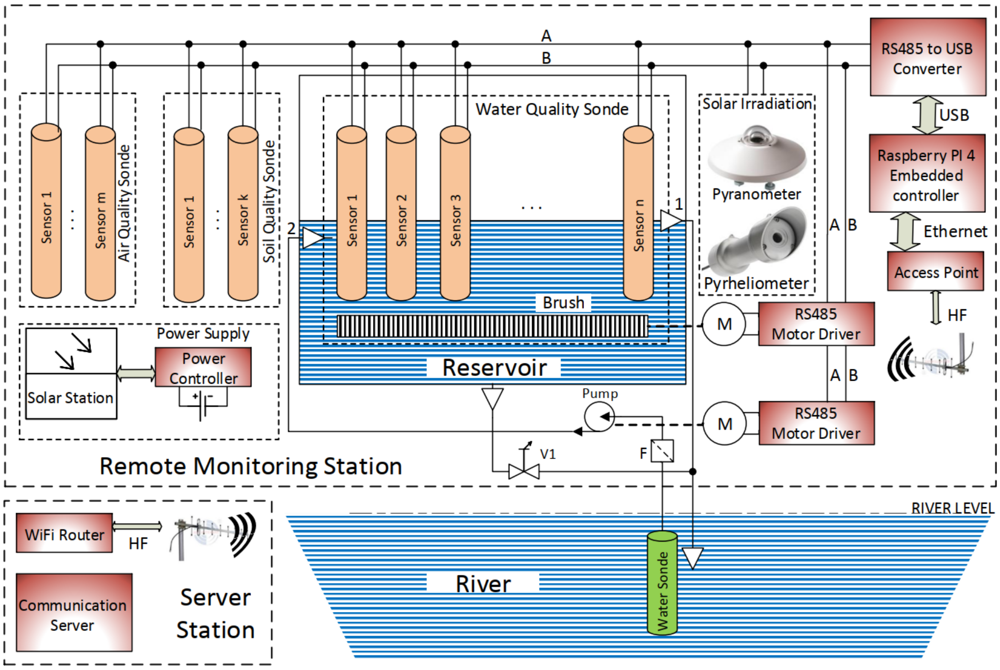

Fig. 3. Schematic diagram of the automatic remote monitoring station.

Information from the sensors is transmitted to the measurement controller via a digital multipoint interface RS485. For this purpose, two data lines (A and B) and two power wires (0 and 5V - not shown in the Fig. 3) are used. This interface provides great flexibility to the system and provides opportunities for its expansion and upgrade. Both motors (of the brush and the pump) are also controlled through it.

Table 3. The specifications of the air quality measurement probe options.

Sensor	Parameter	Min value	Max value
MEMs	Temperature	-40 °C	+85 °C
	Humidity	0% RH	100% RH
Laser scattering	PM1.0	0 μg/m³	1000 μg/m³
	PM2.5	0 μg/m³	1000 μg/m³
	PM10	0 μg/m³	1000 μg/m³
NDIR	CO_2	400 ppm	5000 ppm
MOX	VOC	10 ppm	1000 ppm
Electro-chemical	Formaldehyde	0 ppm	5 ppm
Electro-chemical	Ozone	0 ppm	10 ppm
Analogue sound sensor	Noise level	30dB	130dB

The air quality control section is also connected to the RS485 and provides the measurement of humidity, temperature and particulate matter pollution (PM1.0, PM2.5 and PM10). Table 3 lists the sensor parameters for the air quality probe. All the available options are shown in the Table 3 and can be added as needed.

The soil quality instruments measure the soil moisture and temperature levels. They, like other sensors, use an RS485 interface to communicate with the local controller of the remote monitoring station.

The solar irradiation measurement section controls the levels of the global and direct solar irradiation components. The value of the diffuse irradiation is then calculated, using these two.

The main specifications of the instruments used to measure irradiation levels are given in Tables 4 and 5, respectively, for the pyranometer and pyrheliometer.

Table 4. The pyrheliometer specifications

Parameter	Value
Spectral range (50%)	200 to 4000nm
Reaction time (63%)	< 0.7 s
Reaction time (95%)	< 2 s
Analog output	0 to 1 V
Dependence of sensitivity on temperature (-30 °C до +60 °C)	< 0.5 %
Digital output	RS-485

Table 5. The pyranometer specifications

Parameter	Value
Spectral range (50%)	285 to 2750 nm
Reaction time (63%)	< 0.15 s
Reaction time (95%)	< 0.5 s
Dependence of sensitivity on temperature (-10 ºC to +40 ºC)	< 1 %
Dependence of sensitivity on temperature (-40 °C to +70 °C)	< 2 %
Digital output	RS-485

B. Communication section

The communication section of the remote monitoring station consists of three levels:

- Local Modbus RS485 network segment (between the sensors and the station controller); The information on this level is stored to the controller's SD card before translation to the server. This is done for security purposes;
- Radio network. It may be of four types – GSM/GPRS, WiFi, PMR Modem or Lora-WAN (Fakheri et al., 2024). It transfers data bet-ween the remote station and the fixed Ethernet connection;
- Fxed Ethernet connection. This network segment uses public Internet providers to transmit information to and from the communication server.

In this project, due to the possibility of direct visibility from the stations to points with fixed Internet access, the option with WiFi was selected. This choice additionally makes it possible to ensure low latency of the network and availability of high-speed Internet in the area of the station.

C. Power supply section

A small solar plant that supplies 12V DC power provides autonomous operation of the station. The lithium-ion rechargeable battery allows the station to work up to 3 days, even in the absence of sunlight.

Results

The developed remote station for monitoring surface water, air, soil and irradiation level is under construction and testing. These tests, now, are carried out in manual mode, monthly at the indicated points, with the aim of collecting data on the ecological status of the Veleka River since the start of the project.

The sample of the measurement data obtained by the water quality monitoring probe from Point 1 (Outfall, before observation tower) is presented in Table 5.

The data from the air quality monitoring probe, at the same point and time are presented in Table 6.

Table 5. The sample of the measurement data obtained from Point 1 (Outfall, before observation tower) by the water quality monitoring probe

Date	Hour	Conductivity	DO	Nitrate	PH	ORP	Trubidity	Water temperature
29.7.2023	16:00 PM	1121.5 uS/cm	6.12 mg/l	19.83 mg/l	8.9	475.2 mV	1.5 NTU	24.5 °C
29.7.2023	16:30 PM	1117.0 uS/cm	6.43 mg/l	14.44 mg/l	8.8	474.9 mV	1.4 NTU	24.6 °C

Table 6. The sample of the measurement data obtained from Point 1 (Outfall, before observation tower) by the air quality monitoring probe

	Min	Max	Avg
PM1.0	0ug/m^3	10ug/m^3	0.549ug/m^3
PM2.5	0 ug/m3	20.0 ug/m^3	1.344 ug/m^3
PM10	0 ug/m^3	24.0 ug/m^3	1.515 ug/m^3
Air Humidity	26%	43%	34.60%

Within the reporting period, *in situ* field measurements of soil parameters along the banks of the Veleka River were also carried out. In parallel with tracking the dynamics of the soil parameters from the selected sampling points for taking samples for chemical analysis of surface water.

Surface water samples were analyzed in the laboratory for the presence of priority organic pollutants (volatile organic compounds - benzene, dichloroethane, tetrachloroethene, trichloroethene, hexachlorobutadiene, dichloromethane, trichloromethane, tetrachloromethane; polycyclic aromatic hydrocarbons; polycyclic aromatic hydro-carbons) and heavy metals and toxic elements - copper, arsenic, iron, zinc.

For the purposes of continuous analysis and prediction of the environmental condition and possible problems, the accumulation of a large volume of data over a long period is necessary. The first results show the relatively good condition of the river and its biological diversity. The effect of the economic activity of the people living along the Veleka River is limited for now. The short period of observation does not give us the opportunity to follow trends in the change of its ecological condition.

The construction of the system starts from Point 2A (Table 1 - Pier for motor boats next to the bridge of the village of Sinemorets) and has cover the entire river.

Conclusions

A system for monitoring surface water, soil, air and sunlight levels has been designed and initially tested. For this purpose, an automatic, remote measuring station was developed, intended for installation on the shore, near the riverbed. It is designed for not only collecting and archiving information about the ecological situation along the river, but also periodically sends the data to a communication server.

The monitoring station is designed so that it is possible to measure the values of many parameters characterizing the state of water, soil and air. Thus, only those options that are needed are installed in each site.

For the purposes of assessing the degree of impact of human economic activity on the ecological situation in the Veleka River region, it is necessary:

- to complete the construction of all stations;
- to create an application server to support SCADA system with operator panels, dashboards, reports;
- to create application software that uses the communication server database and generates alerts for environmental degradation.

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References

Aerts, R., Honnay, O., & Van Nieuwenhuyse, A. (2018). Biodiversity and human health: mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*, ldy021. doi: 10.1093/bmb/ldy021

Vassilev, V., Vassilev, R., Yankov, P., Kambourova-Ivanova, N., Uzunov, Y., Georgiev, B., Popgeorgiev, G., Assyov, B., Avramov, S. Tzenova, R. & Kornilev, Y. (2013). *National Action Plan for Conservation of Wetlands of High Significance in Bulgaria*, 2013-2022.

Bowes, M.J., Loewenthal, M., Read, D.S., Hutchins, M.G., Prudhomme, C., Armstrong, L.K., Harman, S.A., Wickham, H.D., Gozzard, E., & Carvalho, L. (2016). Identifying multiple stressor controls on phytoplankton dynamics in the River Thames (UK) using high-frequency water quality data. *Science of the Total Environment*, 569-570, 1489-1499. doi: 10.1016-j.scitotenv.2016.06.239

Rode, M., Wade, A.J., Cohen, M.J., Hensley, R.T., Bowes, M.J., Kirchner, J.W., Arhonditsis, G.B., Jordan, P., Kronvang, B., Halliday, S.J., Skeffington, R.A., Rozemeijer, J.C., Aubert, A.H., Rinke, K., & Jomaa, S. (2016). Sensors in the Stream: The High-Frequency Wave of the Present. *Environmental Science & Technology*, 50 (19), 10297-10307. doi: 10.1021/acs.est.6b02155.

Fakheri, S., Komazec, N., & Najafi, H. (2024). IoT-based river water quality monitoring. *Computational Algorithms and Numerical Dimensions*, 2(4), 216-220. doi: 10.22105/cand.2023.166518.

EPA (2016). EPA Water Security Division. *Online Source Water Quality Monitoring For Water Quality Surveillance and Response Systems*, (MC 140) EPA 817-B-16-003 September 2016.

Petrova, S., Nikolov, B., Tokmakov, D., Lyubomirov, S., Popov, R., Asenov, S., Velcheva, I., Yancheva, V., Georgieva, E., Stoyanova, S. 2024. Sustainable development of rural areas in protected territory – a case study from Strandzha, Bulgaria. *Ecologia Balkanica*, 16(1), 49-57.

PT Ecological Services PVT. LTD. FOREMS *Floating Online River Effluent Monitoring System*. Retrieved from: https://ptecologicalservices.com/surface-water-online-monitoring-system/

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