

INOVATIVNA TEHNOLOGIJA KONTROLE CVETENJA CIANOBAKTERIJ  
INNOVATIVE TECHNOLOGY FOR CYANOBACTERIAL BLOOM CONTROL

Poročilo za širšo javnost  
Layman`s Report

Project / Project: LIFE 12 ENV/SI/000783 LIFE Stop Cyanobloom  
LIFE+ Okoljska politika in upravljanje / LIFE + Environmental Policy and Government



**Upravičenec koordinator / Coordinating Beneficiary**  
Arhel projektiranje in inženiring d.o.o.

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Nacionalni inštitut za biologijo  
Občina Bled

**NIB**  
NACIONALNI INŠTITUT ZA BIOLOGIJO

  
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## CILJI PROJEKTA

V projektu smo se osredotočali na cianobakterije v celinskih vodnih telesih, njihovo zaznavanje in kontrolo neposredno v jezeru.

Glavni cilj projekta je bil prikazati delovanje dveh robotskih plovil s pripadajočima servisnima pristanoma v dveh vodnih telesih z različnima vzorcema pojavljanja cianobakterij.

Namen uporabe robotskih plovil je bil omogočiti on-line način zaznavanja in razlikovanja cianobakterij od preostalega fitoplanktona v vodi in preprečevanje nadaljnega neželenega širjenja cianobakterij neposredno v vodnem telesu brez dodajanja kemikalij. V ta namen smo uporabili elektrolitsko celico, ki tvori hidroksilne radikale, ki so močni oksidanti, neposredno iz vode.

## GLAVNI REZULTATI

- ❑ Vzpostavljena dva servisna pristana z avtomatskim pristajanjem in robotski plovili s pripadajočo opremo za spremljanje fitoplanktona, drugih parametrov vode ter nadzora cianobakterij.
- ❑ Dvoletna demonstracija in optimizacija navigacije in informacijskega sistema za izvajanje meritev on-line in daljinsko upravljanje. Razvoj programske opreme za prenos podatkov njihovo analizo in predstavitev.
- ❑ Dokaz o ustreznosti hkratne uporabe potopnega fikocianinskega in klorofilnega fluorescenčnega senzorja v pretočni merilni komori za zaznavanje in kvantifikacijo cianobakterij v vodnem telesu.
- ❑ Demonstracija selektivne učinkovitosti elektrokemijske oksidacije za cianobakterije, ki preprečuje njihovo nadaljnje razmnoževanje in omogoča kontrolirano sproščanje in inaktivacijo cianotoksinov.

## PROJECT AIMS

The focus of the project were cyanobacteria in freshwater systems, their detection and in-lake control.

The primary goal of the project was to demonstrate the operation of two robotic vessels with accompanied boathouses and docking stations in two freshwater bodies with a different pattern of cyanobacteria occurrence.

The aim of the vessels' operation was to enable early on-line detection and differentiation of cyanobacteria from the rest of the phytoplankton in the water and to prevent further unwanted cyanobacteria proliferation directly in the lake without the addition of chemicals. For this purpose, electrolytic cell was used, producing hydroxyl radicals, which are strong oxidants, directly from water.

## MAIN RESULTS

- ❑ Established two boathouses with automatic docking stations and robotic vessels with accompanying equipment for monitoring of phytoplankton, other water parameters and cyanobacterial control.
- ❑ Two-year demonstration and optimisation of the navigation and information system for on-line measurements and remote control. Software development for data transfer analysis and presentation.
- ❑ Proof of appropriateness of simultaneous use of submersible phycocyanin and chlorophyll fluorescence sensors in continuous flow monitoring chamber for on-site and online detection and quantification of cyanobacteria.
- ❑ Demonstration of a selective efficiency of electrochemical oxidation on cyanobacteria, preventing their further proliferation and enabling controlled release and inactivation of cyanotoxins.

Trajanje projekta / Project duration:

1. Julij 2013 – 31. december 2016 / 1st July 2013 – 31st December 2016

Vrednost projekta / Project value: 1.300.963€

Prispevek EU / EU contribution: 49,97% končnih upravičenih stroškov projekta / of final project eligible costs



Evropska Komisija Finančni instrument LIFE /  
European Commission Financial Instrument LIFE



## UZADJE IN CILJI PROJEKTA

Cianobakterije lahko izločajo nevarne cianotoksine in so vzrok neprijetnega vonja in okusa vode. Njihovo vidno in masovno pojavljanje imenujemo cianobakterijsko cvetenje. Vzrok za nastop cvetenja je največkrat evτροφnost voda. Pojavljanje cianotoksinov lahko vodi v zaprtje voda za rekreacijske namene, povzroča težave pri zagotavljanju pitne in namakalne vode, gospodarsko škodo v ribogojnicah, itd.



Za zmanjšanje tovrstnih nevarnosti je v prvi vrsti nujno zagotoviti ukrepe za preprečevanje obremenjevanja voda. Ker preventivni ukrepi mnogokrat ne zadostujejo, so nujno potrebne rešitve za zgodnje odkrivanje pojavljanja nevarnosti in preprečevanje cvetenja cianobakterij ne glede na stanje vodnega telesa.

## METODOLOŠKI PRISTOP

### Odkrivanje cianobakterij v jezeru

V okviru projekta smo uporabili za odkrivanje cianobakterij neposredno v vodi specifično fluorescenco fotosintetskih barvil cianobakterij in evkariontskih alg. Sočasna uporaba klorofilnega in fikocianinskega senzorja nam je omogočila razlikovanje in kvantifikacijo cianobakterij in alg v realnem času. S tem smo lahko pridobili veliko količino podatkov o pojavljanju fitoplanktona in bakterioplanktona v prostoru in času z bistveno manj laboratorijskega dela.

### Kontrola rasti cianobakterij v jezeru

Za takojšnje preprečevanje nadaljnje razrasti cianobakterij v jezeru smo v okviru projekta izbrali metodo elektrokemijske oksidacije z uporabo elektrolitske celice. V njej uporabljamo elektrodne materiale z visoko kapaciteto tvorbe hidroksilnih radikalov ( $\text{HO}^\circ$ ) neposredno iz vode.  $\text{HO}^\circ$  so kratko obstojni a zelo močni oksidanti na katere so cianobakterijske celice bolj občutljive kot drugi organizmi.



## PROJECT BACKGROUND AND GOALS

Cyanobacteria can release dangerous cyanotoxins and are the source of the unpleasant odour and taste of water. Their massive occurrences in water are called cyanobacterial blooms. The cause for blooming is water eutrophication. The presence of cyanotoxins in the water can lead to the closure of water bodies for recreation, problems in the provision of clean drinking and irrigation water, economic damage aquacultures, etc.



To reduce such threats is first and foremost necessary to ensure measures to prevent water pollution. As preventive measures are often not sufficient, the solutions for the early detection of the occurrence of cyanobacterial hazards and prevention of their bloom is necessary regardless of the status of water bodies.

## PROJECT METHODOLOGY

### Detection of cyanobacteria in the lake

A specific fluorescence of photosynthetic pigments was used in the project to detect cyanobacteria and eukaryotic algae directly in the water body. The simultaneous use of chlorophyll and phycocyanin sensor has enabled the differentiation and quantification of cyanobacteria and algae in real time. In this way, we gained a large amount of data on the spatial and temporal occurrence of phytoplankton and bacterioplankton by substantially less laboratory work.

### In-lake control of the growth of cyanobacteria

For immediate prevention of further growth of cyanobacteria in the lake, we choose the method of electrochemical oxidation the project with the application of electrolytic cells. They are equipped with advanced electrode materials with a high capacity of the formation of hydroxyl radicals ( $\text{HO}^\circ$ ) directly from water. The  $\text{HO}^\circ$  are short lasting a very powerful oxidising agent to which the cyanobacterial cells are more sensitive than the other organisms.

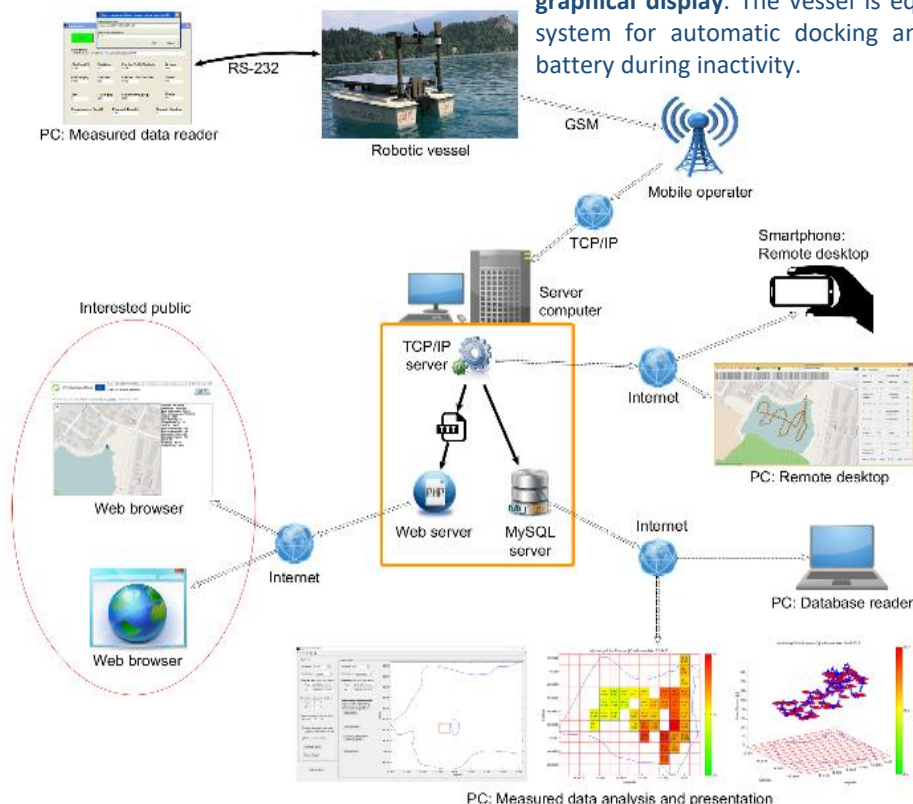


Vgradnja obeh sistemov v robotsko plovilo omogoča vzpostavitev zgodnjega obveščanja o možnosti pojava škodljivega cvetenja in hkratno preprečevanje razraščanja, pri čemer v vodno telo ne vnašamo nikakršnih kemikalij, ki bi dodatno prispevale k tvorbi jezerskega sedimenta.

The installation of both systems into a robotic vessel enables the establishment of early warning system on harmful cyanobacteria occurrence and simultaneous prevention of their proliferation without the addition of chemicals, which would contribute to the formation of the sediment.

Robotsko plovilo napaja **sončna energija**. Plovilo lahko samodejno pluje po točkah, ki jih določi uporabnik z računalniškim programom. Trodimenzionalno lokalizacijo, koncentracijo, kot tudi informacijo o fiziološkem stanju cianobakterij dobimo z merjenjem fluorescence cianobakterijskih pigmentov. V ta namen uporabljamo **klorofilni in fikocianinski senzor fluorescence**. Z uporabo **elektrolitske celice**, ki tvori kratko obstojne hidroksilne radikale neposredno iz vode, uravnavamo razraščanje cianobakterij. Z izbrano jakostjo in dolžino trajanja elektrolize **razgrajujemo cianotoksine**, povzročamo **celični razpad** cianobakterij ali zgolj **zaviramo** njihovo **nadaljnjo razmnoževanje**. Posebej razvit mehanski sistem omogoča **odvzem vzorcev vode** iz spremenljive globine za natančnejšo laboratorijsko obdelavo. Plovilo prek GSM komunikacije javlja pridobljene **podatke v realnem času**, zato ima uporabnik vedno natančno sliko o trenutnem stanju vodnega telesa, ki jo lahko spremlja preko spletne aplikacije. Poleg senzorjev fluorescence plovilo javlja informacijo o **temperaturi vode, elektro prevodnosti, pH, koncentraciji raztopljenega kisika, položaju na vodnem telesu, jakost vetra in fotografsko sliko**. Uporabniku prijazna programska oprema omogoča **obdelavo merjenih podatkov in grafični prikaz**. Plovilo je opremljeno z naprednim sistemom za avtomatsko pristajanje in polnjenjem rezervnih akumulatorjev v času mirovanja.

The robotic vessel is powered by **solar energy**. The vessel can automatically follow the points on the water specified by the user by a computer program. The three-dimensional localisation, concentration, as well as information about the physiological status of cyanobacteria is obtained by measuring the fluorescence of cyanobacterial pigments. For this purpose, the **chlorophyll and phycocyanin fluorescence sensors** are used. With the **electrolytic cell**, producing short-lived hydroxyl radicals directly from the water, prevention of further cyanobacteria proliferation is achieved. With the selected intensity and duration of the electrolysis, a **degradation of cyanotoxins** is achieved, **cellular decomposition** of cyanobacterial cells or only an **inhibition of their further proliferation**. A specially developed mechanical system allows the **collection of water samples** from variable depths for accurate laboratory processing. The vessel **reports real-time data** to the user via GSM communication. The user, therefore, obtains an accurate picture of the current state of the water body, which can also be followed via a web application. In addition to fluorescence sensors, the vessel reports the information on water **temperature, electrical conductivity, pH, dissolved oxygen concentration, the position in the water body, the strength of the wind and the photographic image**. User-friendly software **allows processing of measured data and their graphical display**. The vessel is equipped with an advanced system for automatic docking and charging of the spare battery during inactivity.



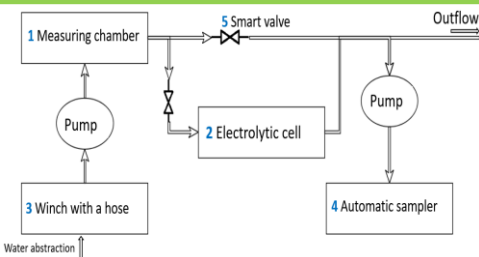
## INFORMACIJSKI SISTEM ZA PRENOS IN PREDSTAVITEV MERJENIH PODATKOV

Integrirani informacijski sistem omogoča tridimenzionalni vpogled v stanje vodnega telesa. Plovilo z vsemi senzorji poroča operaterju o GPS lokaciji, globini, prisotnosti alg in cianobakterij in drugih vodnih parametrih. Plovilo pošilja podatke v realnem času preko GSM komunikacije za njihov prikaz na spletni strani. GSM modul pošilja podatke tudi oddaljenemu TCP/IP serverju operaterja, kjer se podatki shranjujejo v MySQL podatkovno bazo. Uporabniku prijazno programsko orodje omogoča analizo in prikaz podatkov.

## INFORMATION SYSTEM FOR TRANSFER AND PRESENTATION OF MEASURED DATA

Integrated information system enables a 3-D view into the state of the water body. A vessel with its sensors reports to the operator about its GPS location, depth, the presence of algae and cyanobacteria and other water parameters. The vessel sends the data in real-time via GSM communication for their presentation at the website. GSM module sends the data also to a distant TCP/IP server of the operator, where the data is saved in MySQL database. User-friendly program tool enables data analysis and graphical presentation.



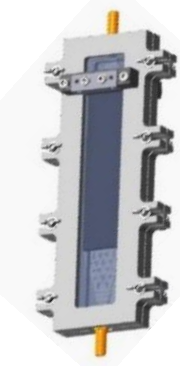
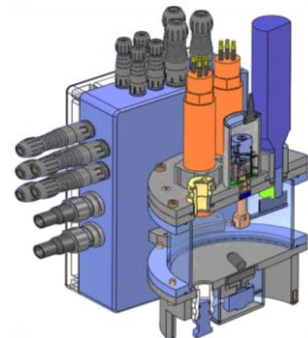


**POVEZANOST SISTEMOV MERJENJA, TRETIRANJA IN VZORČENJA** omogočajo plovilu črpanje vode na različnih globinah za izvedbo meritev, odločitev o vklopu elektrolitske celice, ali odvzem vzorcev vode za nadaljnje laboratorijske analize.

**INTEGRATED MEASURING, TREATING AND SAMPLING SYSTEMS** in the vessel enables pumping of water from various depths, decision-making upon activating electrolytic cell or sampling the water for further laboratory analysis.

**PRETOČNA MERILNA KOMORA ZA MERITVE PARAMETROV VODE** omogoča simultano merjenje iz petih senzorjev (npr. fikocianin, klorofil, temperatura, kisik, prevodnost, pH). Potopni senzori fluorescence z avtomatsko čistilno metlico se uporabljajo za kvantifikacijo alg in cianobakterij.

**CONTINUOUS FLOW CHAMBER FOR MEASURING WATER PARAMETERS** enables parallel measuring with five sensors (e.g. phycocyanin, chlorophyll, temperature, oxygen, conductivity, pH). Submersible fluorescence sensors with automatic cleaning brush are used for algae and cyanobacteria quantification.

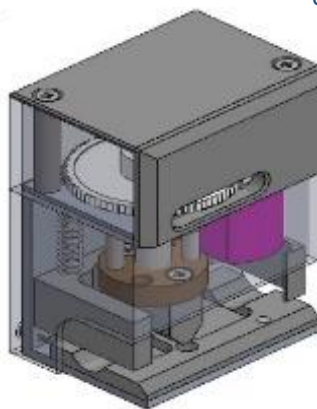


**ELEKTROLITSKA CELICA ZA PREPREČEVANJE RAZMNOŽEVANJA CIANOBAKTERIJ IN RAZGRADNJO CIANOTOKSINOV** je opremljena z borom dopiranimi diamantnimi (BDD) elektrodami za elektrokemijsko stimulacijo cianobakterij neposredno v vodi. Znotraj celice s z dovajanjem električnega toka nastajajo kratko obstojni hidroksilni radikali ( $HO^\circ$ ). BDD elektrode so napredne inertne elektrode, z najvišjim potencialom tvorbe  $HO^\circ$ , ki omogočajo inhibicijo in razgradnjo cianotoksinov in preprečujejo nadaljnjo razraščanje cianobakterij.

**ELECTROLYTIC CELL FOR CYANOBACTERIA GROWTH CONTROL AND CYANOTOXIN DEGRADATION** contains boron doped diamond (BDD) electrodes for electrochemical stimulation of cyanobacteria directly in water. Short-lived hydroxyl radicals ( $HO^\circ$ ) are produced with supplied current inside the cell. BDD electrodes are advanced inert electrodes with the highest potential of generating  $HO^\circ$ , which inhibit and degrade cyanotoxins and prevent cyanobacterial overgrowth.

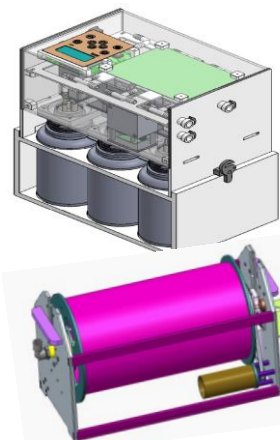
## REGULACIJA PRETOKA VODE S PAMETNIMI VENTILI

Sistem pretoka vode na plovilu in avtomatski vzorčevalnik sta opremljena s pametnimi ventili. Motor ventila in integrirana elektronika omogočata avtomatski nadzor in integracijo ventilov v večji sistem s sinhroniziranim delovanjem. Regulacija pretoka poteka s koračnim stiskanjem cevi. Oblikovanost ventila omogoča enostavno zamenjavo cevi (npr. za preprečitev kontaminacije vzorca), uporabo cevi različnih velikosti in mehanskih lastnosti.



## WATER FLOW REGULATION BY SMART VALVES

Water flow system in the vessel and the automatic sampler are equipped with smart valves. The motor of the valves and integrated electronics enable an automatic control and integration of valves into a bigger system with synchronised functioning. Flow regulation is carried out with a stepwise compression of the hose. The design of the valves allows for easy replacement of the hose, the use of hoses of different diameters and mechanical properties.



## AVTOMATSKI VZORČEVALNIK Z MOTORNIH KOLUTOM ZA CEV

Vzorčevalnik omogoča odvzem šest eno-litrskih vzorcev vode s pomočjo motornega koluta s cevjo. Elektronika vzorčevalnika omogoča časovno in globinsko nastavljivo črpanje vzorcev in zaznavanje možnih napak (puščanje vzorčevalne posode, odpoved črpalke, zamašitev cevi) v izogib razlitju z avtomatskim izklopom delovanja.

## WATER AUTOSAMPLER WITH MOTORIZED HOSE REEL

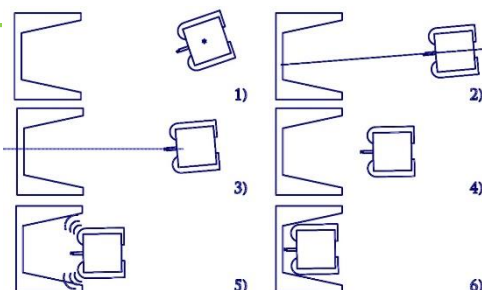
Sampler allows withdrawal of six one-litre water samples by winding the hose. Electronics of the sampler enables the time and depth adjustable water abstraction and a detection of possible defects (leaks of the containers, pump damage, clogging of a pipe) to avoid spillage with automatically shutting off the operation.

## AVTOMATSKI SISTEM PRISTAJANJA

Plovilo lahko upravljamo ročno ali daljinsko preko računalnika. Po opravljeni nalogi, se plovilo vrne v bližino pristana, kjer se prične postopek avtomatskega pristajanja z uporabo kompasa in robotskega vida.

## AVTOMATSKI SISTEM PRISTAJANJA

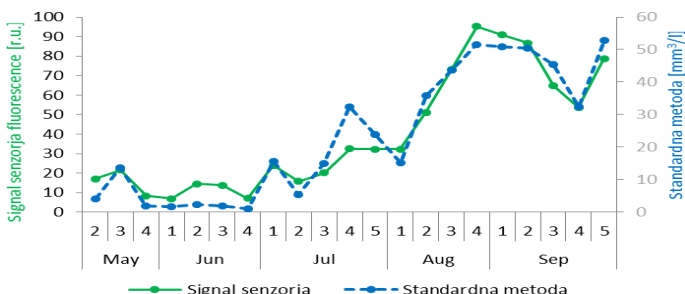
The vessel can be navigated manually or by remote control using the computer. After the accomplished mission, the vessel returns to the vicinity of the docking station where automatic docking starts with the help of a compass and robotic vision.



# REZULTAI PROJEKTA

## Skladnost on-line meritev fluorescenčnih senzorjev s standardnimi metodami vrednotenja fitoplanktona

Rezultati meritev s senzorji fluorescence so pokazali ujemanja s standardnimi metodami vrednotenja fitoplanktona, kot je določanje biovolumna. S predhodnim umerjanjem lahko signal sensorja pretvorimo v biološke enote.



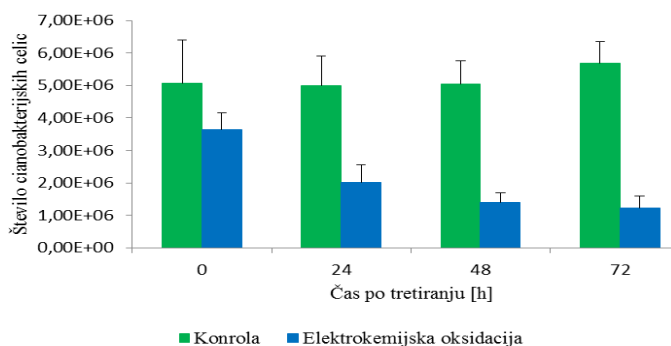
# PROJECT RESULTS

## Correlation between on-line measurements of fluorescence sensors and standard methods for phytoplankton evaluation

Results from monitoring with fluorescence sensors showed there is a high correlation with standard methods for phytoplankton evaluation, like biovolume analysis. The signal from the sensor can be calculated to biological units by the previous calibration.

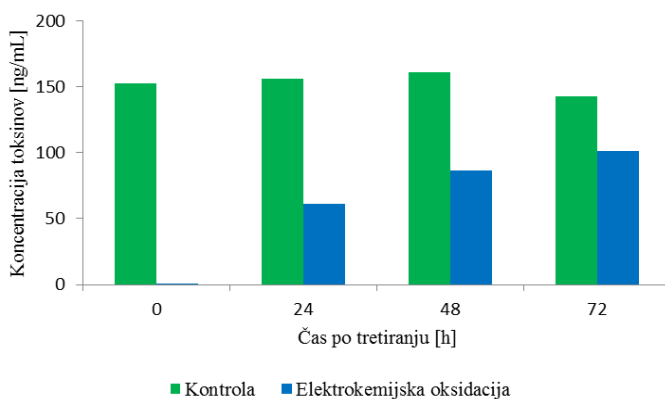
## Učinkovanje elektrokemijske oksidacije z uporabo elektrolitske celice vodi v zmanjšanje števila cianobakterijskih celic in koncentracije cianotoksinov

Vpliv elektrokemijske oksidacije na številčnost celic *Microcystis aeruginosa*, ki je pogost cianobakterijski predstavnik evtrofnih vodnih teles.



The effect of electrochemical oxidation on the number of cells of *Microcystis aeruginosa*, which is a common cyanobacteria in eutrophic water bodies.

Spremljanje koncentracijam sproščenih cianotoksinov v vodo po izvedbi elektrokemijske oksidacije (v času 0). Uspeli smo zmanjšati koncentracijo zunajceličnih mikrocistinov cianobakterije *Planktothrix rubescens* že takoj po tretiranju. V nadaljevanju koncentracija sproščenih toksinov v vodo ni preseгла koncentracije kontrolnega vzorca.



Monitoring of released cyanotoxins concentration in the water after electrochemical oxidation (at time 0). We have achieved to reduce the concentration of extracellular microcystins of *Planktothrix rubescens* instantly after the treatment. Later on, the concentration of the released toxins did not exceed the concentration of the control sample.

# OCENA KAPACITETE

Obstoječa velikost plovila in fotonapetostnih celic omogoča vgradnjo **treh elektrolitskih celic** površine 60 cm<sup>2</sup>. V primeru ribnika bi to zadostovalo za obdelavo **9** oziroma **2,8 m<sup>3</sup>** vode v enem tednu oziroma dveh dneh z zaznano previsoko koncentracijo cianobakterij, s ciljem dosegati **80% zmanjšanje** števila celic v oblaku cianobakterij. Hkrati bi to zadostovalo za kontrolo **1** oziroma **0,27 hektara vodne površine**, ob predpostavki, da je potrebno tretirati zgornjih 10 cm vodnega stolpca ter, da cianobakterijski oblak prekriva 1% vodne površine. Predvidena je bila uporaba gostote toka 50 mA/cm<sup>2</sup> elektrodne površine. Glede na to, da je naš cilj zgolj vzdrževanje cianobakterijske populacije pod kritično mejo (in ne popolno uničenje cianobakterijskih celic), lahko predpostavimo nižjo učinkovitost tretiranja, ki s tem omogoča **kontrolno večje vodne površine**. Tretiranje je potrebno ponoviti večkrat v času sezone cvetenja cianobakterij.

# EVALUATION OF THE CAPACITY

The existing boat size and the capacity of the photovoltaic panels used in the project would allow installation of **3 electrolytic cells** with the 60 cm<sup>2</sup> electrode surface. This would serve for **9 and 2.8 m<sup>3</sup>** of water, if we would like to treat the detected affected water volume in **one week and two days**, respectively and achieve **80% reduction** of cells in the treated cloud of cyanobacteria. This would allow controlling **1 and 0.27 hectares of water surface** if we presume that the treatment of upper 10 cm water layer would be needed and that cyanobacterial cloud covers 1% of the water surface. The applied current density of 50mA/cm<sup>2</sup> was taken into account. Since the goal is to keep the cyanobacterial population below the critical level (and not to completely destroy the cells), a lower reduction efficiency could be needed, which then **allows the control of a larger surface area**. Treatment would need to be repeated several times during the cyanobacterial blooming season.

## KONČNI UPORABNIKI / END-USERS

### UPRAVLJAVCI VODNIH TELES / MANAGERS OF WATER BODIES

- Rekreatijske in kopalne vode / Recreation and bathing waters
- Akumulacije pitne in namakalne vode / Drinking and irrigation reservoirs
- Ribogojnice / Aquacultures
- Akumulacije elektrarn / Power plant accumulations

### NADZORNE INŠTITUCIJE / SUPERVISORY INSTITUTIONS

- Državne okoljske agencije / Governmental environmental agencies
- Certificirani laboratoriji za vode / Certified laboratories performing water analysis
- nacionalni inštituti za javno zdravje / National institutes for public health

### RAZISKAVE IN RAZVOJ / RESEARCH AND EDUCATION

- Visokošolske inštitucije z okoljsko orientacijo / Higher education institutions with environmental orientation
- Raziskovalni inštituti / Research institutes (with water and environmental departments)
- Srednje šole (okolje, elektrotehnika, strojništvo, robotika) / High schools (environment, electro-technik, mechanical engineering, robotics)

## POTENCIAL UPOTABE IN KORISTI / APPLICABILITY POTENTIAL AND BENEFITS

- Nižji stroški monitoringa / Reduction of monitoring costs
- Nižji stroški kontrole cianobakterij / Reduction of cyanobacteria control costs
- Natančna prostorska in časovna slika kakovosti vode z zgodnjim sistemom obveščanja / Detailed spatio-temporal insight into water quality, providing early warning
- Samostojno vzdrževanje kakovosti vode / Self sustaining of the water quality
- Izvajanje raziskav (ekologija voda, kontrola cianobakterij, robotika, mehanika elektronika) / Performing research (water ecology, cyanobacteria control, robotics mechanics, electronics)
- Demonstracije v izobraževanju / Demonstrations in education
- Pridobitev statusa ponudnika storitve kontrole cianobakterij / Becoming a service provider for cyanobacteria control

## PRENOSLJIVOST TEHNOLOGIJE TECHNOLOGY TRANSFERABILITY

Jezera in akumulacije: meritve alg, cianobakterij in osnovnih fizikalno-kemijskih parametrov /

Lakes and reservoirs: measurements of algae, cyanobacteria and basic physical and electrical parameters

Jezera in akumulacije: kontrola cianobakterij z elektrokemijsko oksidacijo / Lake and reservoirs: cyanobacteria control with electrochemical oxidation

Akvaponika in biotehnologija (produkcija alge biomase in biomolekul): zaznavanje različnih parametrov kakovosti vode (hranila, organska obremenitev) / Aquaponics, biotechnology (algal biomass and biomolecules production): sensing variety of water quality parameters (nutrients, organic load)

Elektrokemijska oksidacija v odpadni in pitni vodi: odstranjevanje obstojnih organskih onesnažil / Electrochemical oxidation in wastewater and drinking water treatment: removal of persistent organics

Prenos podatkov robotsko vozilo – operater / Robotic vessel to operator data transfer

Mapiranje in prenos podatkov v večjem obsegu / Bigger scale mapping applications

## Nadzorne meritve

- Informacije o stanju vode v realnem času.
- Enakomeren dostop do vseh delov vodnega telesa in vzorčenje na izbranih lokacijah.
- Večja prostorska in časovna resolucija – tridimenzionalna slika vodnega telesa.
- Optimizirana strategija vzorčenja z utemeljenimi odločitvami o nadaljnjih lokacijah in časih vzorčenja.
- Kvalitativno in kvantitativno zaznavanje fitoplanktona.
- Ocena fiziološkega stanja fitoplanktona.
- Ugotavljanje prisotnosti stresa in stresorjev v vodnem okolju.
- Vzpostavitev zgodnjega sistema obveščanja.
- Zaznavanje in sledenje položaju in premikanju cianobakterijskega sveta.
- Pridobivanje natančnejših podatkov z nižjimi stroški na manj delovno intenziven način.

## Kontrola cianobakterij v jezeru

- Lokalizirana kontrola na izbranih območjih.
- Preventivno delovanje temelječe na sočasnem monitoringu in kontroli rasti cianobakterij.
- Kurativno delovanje s sočanim delovanjem na cianobakterije in njihove toksine.

## Avtomatizirano in energetsko učinkovito delovanje

- Cenovno konkurenčna in tehnološko napredno robotsko plovilo.
- Trajnostna raba energije z delovanjem na sončno energijo brez vnosa kemikalij.
- Samostojna uporaba posameznih komponent plovila.

## Monitoring

- Real-time information on the state of water.
- Even accessibility to all parts of the water body and collection of samples at a selected location.
- Higher spatial and temporal resolution - a three-dimensional snapshot of the water body.
- Optimised sampling strategies allowing a reasoned decision on the further time and location of sampling.
- Quantitative and qualitative detection of phytoplankton.
- Assessment of the physiological state of the phytoplankton.
- Determining the presence of stress and stressors in the aquatic environment.
- Establishment of early warning.
- Detecting and tracking the position and movement of cyanobacterial bloom.
- Obtaining detailed data with lower costs and less labour-demanding way.

## In-lake cyanobacteria control

- Localized control in selected areas.
- Preventive action based on synchronised cyanobacteria monitoring and growth control.
- Curative actions with simultaneous cyanobacteria and cyanotoxins destruction.

## Automated energy efficient operation

- Cost competitive and technologically advanced robotic vessel.
- Sustainable energy use with solar powered operation without artificial chemicals input.
- Standalone use of the individual components of the vessel.

Koordinator projekta

Project coordinator

**ARHEL d.o.o.**

projektiranje in inženiring

Uporaba elektronike in informatike v okoljskih rešitvah.  
Razvoj produktov in storitev za širok spekter uporabe

- R&R po meri naročnikov
- Vgrajene programske rešitve
- Proizvodnja in testiranje končnih produktov
- Serijska proizvodnja
- Rešitve na ključ
- Razvoj prototipov s področja elektronike, mehanike in senzorjev.

Kontakt / Contact:

Arhel d.o.o. Pustovrhova 15

1210 Ljubljana - Šentvid, Slovenia EU

E-mail: [info@arhel.si](mailto:info@arhel.si)

[www.arhel.si](http://www.arhel.si)

[www.lifetopcyanobloom.arhel.si](http://www.lifetopcyanobloom.arhel.si)

**Application of electronics and informatics in environmental solutions. Development of individual solutions with a wide range of applications**

- Customer-specific R&D
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- Production and testing of final products
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