BlooWater

"Technological solutions and tools for the integrated management of drinking water reservoirs contaminated by Cyanobacteria and cyanotoxins: BLOOWATER project."

Maria Sighicelli (ENEA)-Italy

Francesco Fatone (University of Marche)-Italy

Don Pierson (University of Uppsala)- Sweden

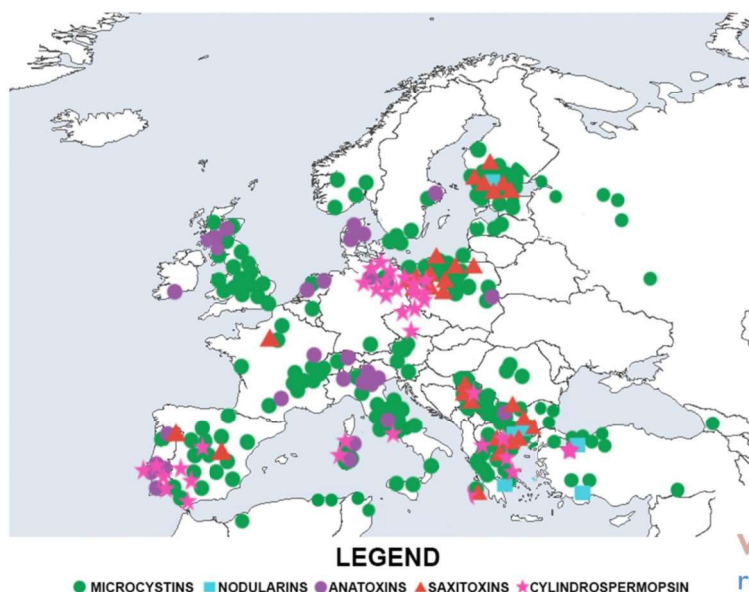**Christian Vogelsang (Norwegian Institute for Water Research)**

ECOMONDO
THE GREEN TECHNOLOGY EXPO

Water JPi

ENEA   UNIVERSITÀ POLITECNICA DELLE MARCHE   NIVA

Fig. 6 Geographical distribution of the most commonly reported cyanotoxins in Europe

LEGEND
- ● MICROCYSTINS ■ NODULARINS ● ANATOXINS ▲ SAXITOXINS ★ CYLINDROSPERMOPSIN

GENERAL CONTEXT

PROJECT OBJECTIVES

WP1- to design and develop a monitoring system of bloom based on the integration of remote and proximal sensing technology and in situ data sampling.

WP2- to test two different methods for simulating the occurrence of cyanobacteria blooms: Process based (PB) modeling and Machine learning (ML) based methods.

WP3- to study and validate sustainable and efficient technologies for the treatment of water affected by cyanobacteria toxicity;
to start the laboratory tests to determine the design parameters for the pilot scale polymer-enhanced ultrafiltration (PEUF) demonstration.

WP4- to develop of an integrate DSS-GIS approach for the water cycle management.

2019-2023

www.waterjpi.eu

SCIENTIFIC AND TECHNOLOGICAL PROGRESS

BlooWater

WP1

➢ to define and plan protocol to collect and compare water sampling data with remote sensing data
➢ to test drone/sensor system in water sampling winter campaign
➢ ongoing image processing

WP2

➢ to develop the data sets needed to test either of these approaches;
➢ to set up PB models on the lakes chosen as test sites by BLOOWATER

WP3

➢ to finalized a practical report on data performances and economical assessment of conventional technologies for cyanobacteria reduction
➢ Bench Scale Testing of PEUF and reference technology
➢ Processes design, development and field validation of the promising water treatment technologies

WP4

➢ to define data set concerning the characteristics of the pilot action area
➢ and mapping of relevant stakeholder.

Water JPI

ENEA   NIVA   ECOMONDO

BLOOWATER
WP1 Monitoring System

Maria Sighicelli

ENEA

www.waterjpi.eu

Overview on Monitoring Goals WP1

Milestones

Identification and characterization of study areas made
Definition of operational procedures for integrated monitoring campaigns in the pilot area
Integrated bloom data collection

Deliverables ongoing
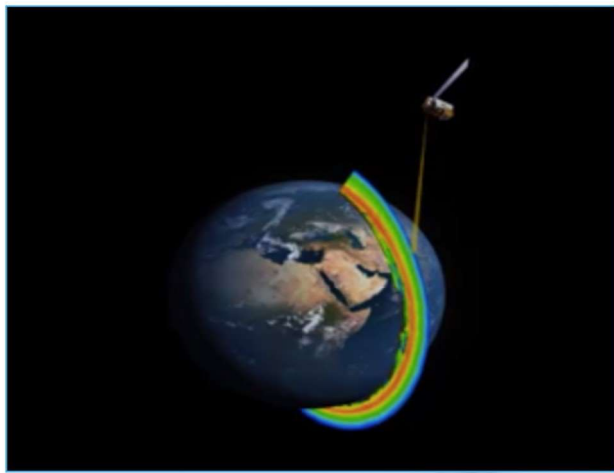
Design of Cyano-HAB Database

Progress

- Testing sensor for water image acquisition, but not yet complete
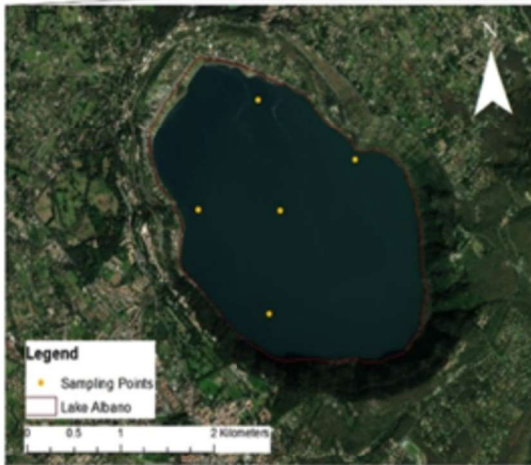- Development of algorithms for image processing

BlooWater

INTEGRATION OF REMOTE SENSING TECHNOLOGY & IN SITU DATA SAMPLING

March-October 2019 water sampling campaigns

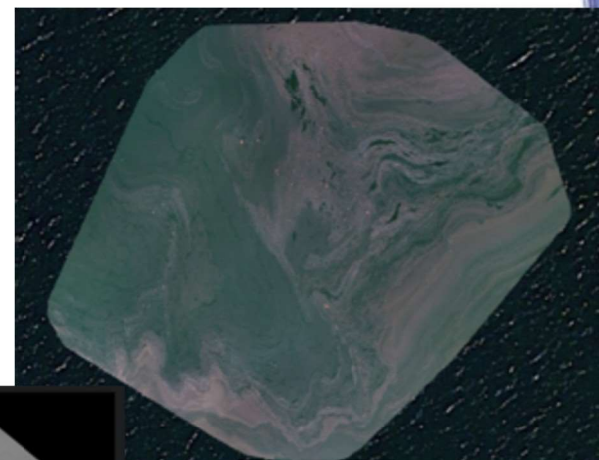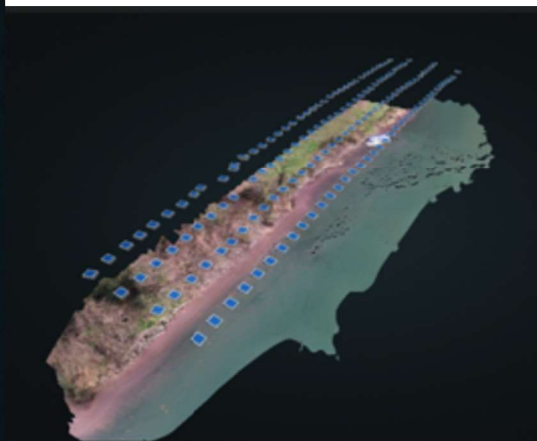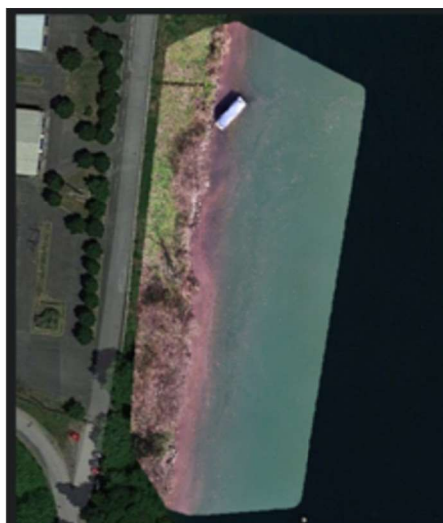**Albano Lake: Italian area pilot WP1**

Paper submitted under review:

- *An integrated approach to chlorophyll monitoring in surface freshwater: the case-study of Lake Albano (Central Italy).* M. Sighicelli, M. Perrone, F. Lecce, M. Malavasi, M. Scalici. In Water;

- *Water mixing conditions influence Sentinel-2 monitoring of chlorophyll content in monomictic lakes.* M. Perrone, M. Scalici , L. Conti, D. Moravec, J. Kropáček, M. Sighicelli, F. Lecce, M. Malavasi. In Ecological Remote Sensing
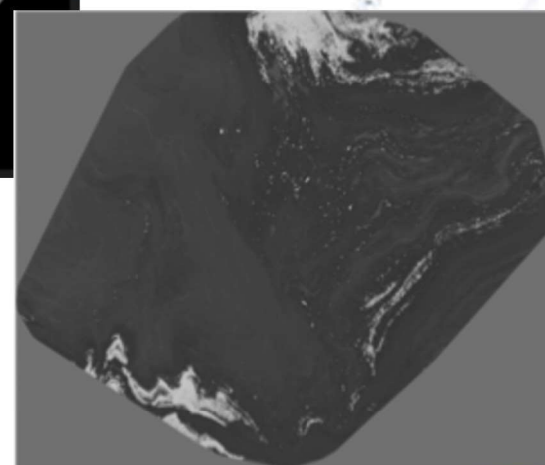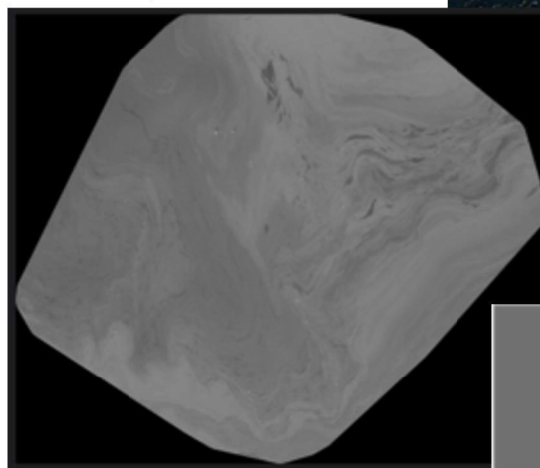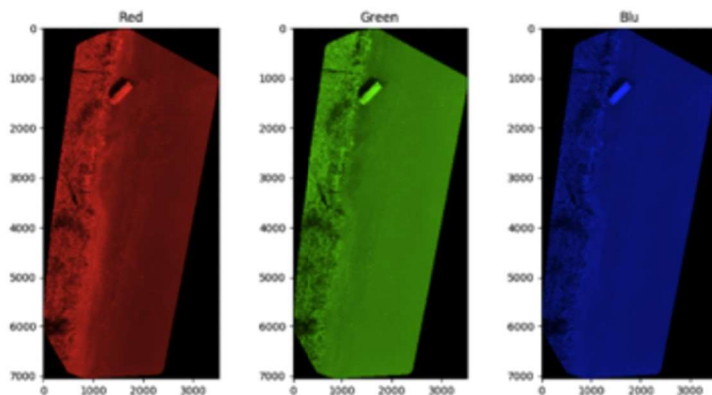
Legend
- Sampling Points
- Lake Albano

Water JPI

www.waterjpi.eu

ENEA

NIVA

ECOMONDO
THE GREEN TECHNOLOGY EXPO

drone/sensor system has been tested and used during the water sampling campaign (11/2020-02/2021) (11/2021-02/2022)

BLOOWATER
WP2 Modelling

Don Pierson

Uppsala University

Overview on Modelling Goals WP2

Milestones

M3 Final decision on case study sites made
M9 GOTM hydrothermal model setup and calibrated for all case study sites.
M18 SELMA water quality model setup and calibrated for all case study sites.
M21 Machine learning algorithms tested on all case study sites

Deliverables

M6 Publicly available data archive of all data used to force and calibrate lake water quality models
M24 Manuscript to be submitted for publication comparing the simulations of cyanoHAB blooms using mechanistic models and machine learning methods.

Progress

- Data archive created,
- Hydrothermal model setup Sweden and Norway
- Water quality model setup Sweden and Norway
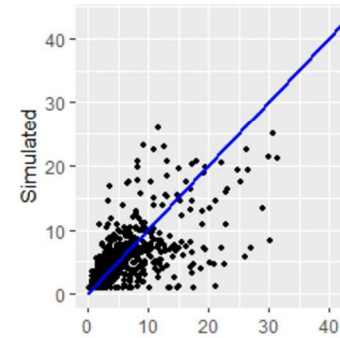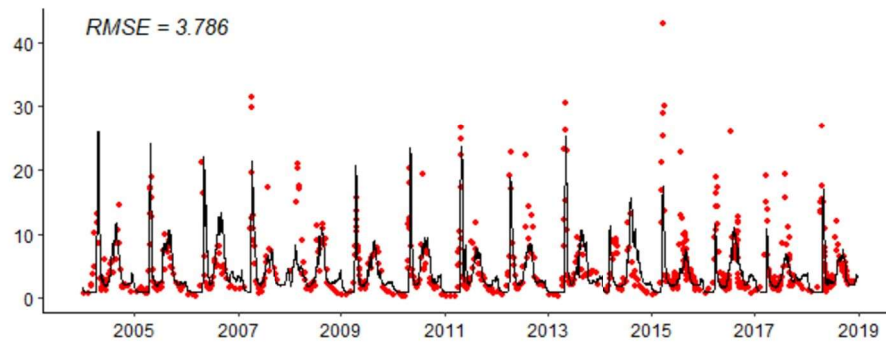- Work on machine learning underway Postdoc just hired

www.waterjpi.eu

Progress on Process Based Modelling

Good results for simulation of total chlorophyll concentration

Process based models of cyanobacteria derived chlorophyll concentration are less successful than that for total chlorophyll

Some promise in simulating the correct timing of the blooms. But so far not good enough for management purposes

Total Phytoplankton Chlorophyll Lake Erken 3 Meters

RMSE = 3.786

2006 Cyanobacterial Chlorophyll Lake Erken 3 Meters

RMSE = 0.82

Measured Red Points
Simulated Black Lines
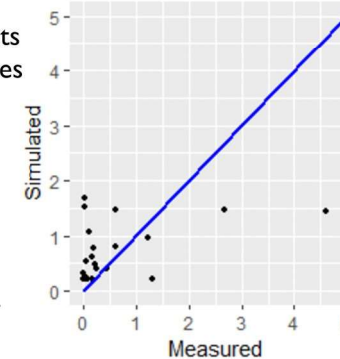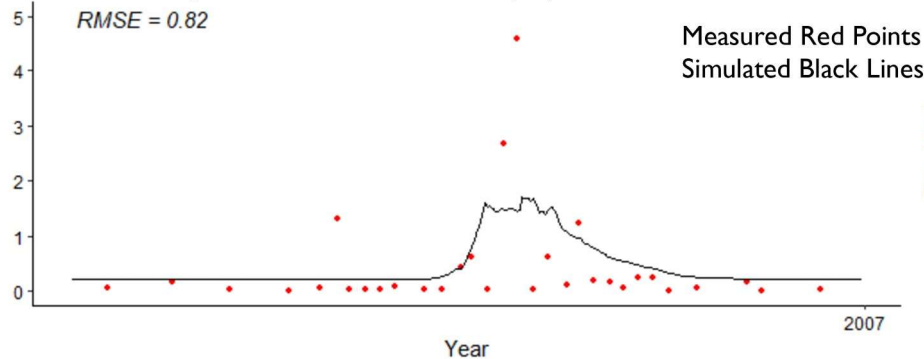
2014 Cyanobacterial Chlorophyll Lake Erken 3 Meters

RMSE = 1.344
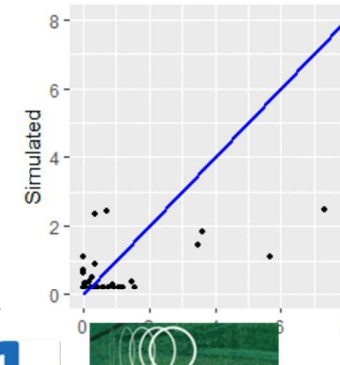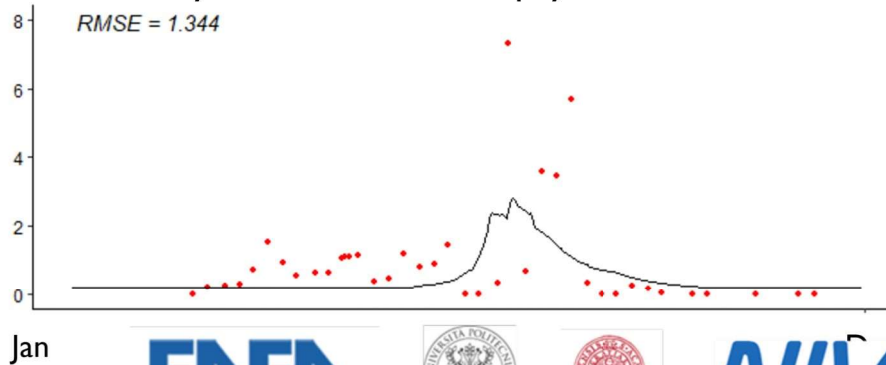
Progress on Machine Learning

- New post hired Shuqi Lin to work on machine learning algorithms. Started 15 March Much Delayed Due to COVID
- Initial testing on using Lake Erken Total Chlorophyll concentration as shown below. Machine learning models can outperform the processed based models

Next Steps

- Test other machine learning algorithms
- Evaluate cyanobacteria in addition to total chlorophyll
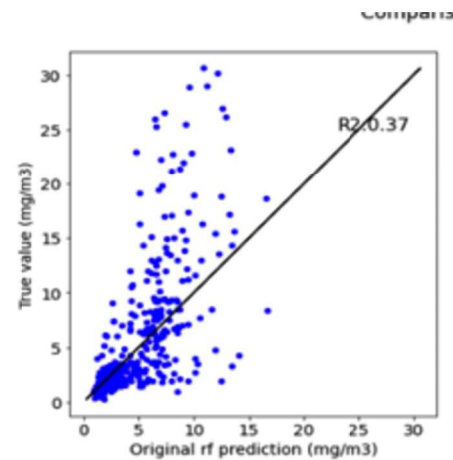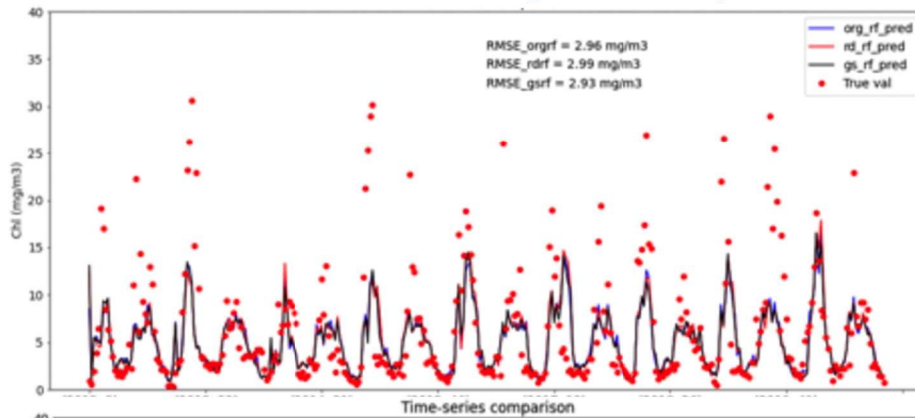- Include information from processed based models into machine learning algorithms

Random Forrest Algorithm Attempt 1

Random Forrest Algorithm Attempt 2
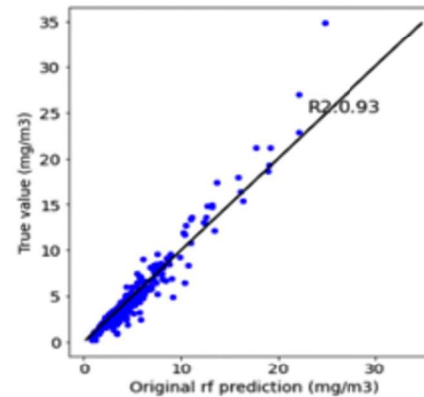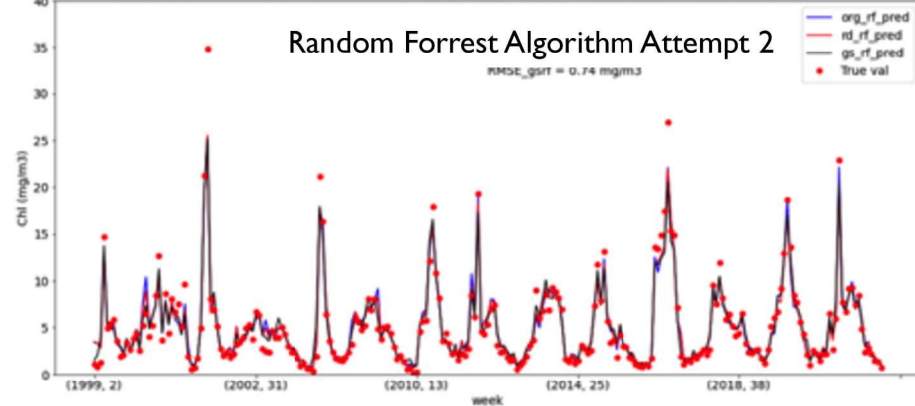
Most important Input Data Attempt 2

	features	FI
4	TotP(mmole/m3)	0.310661
7	PO4(mmole/m3)	0.224303
0	week_num	0.091718
11	in_NH4 (mole/l)	0.062449
6	NOX(mole/m3)	0.062180
2	inflow_temp	0.055247
1	inflow(m3/s)	0.048018
5	NH4(mmole/m3)	0.039010
3	Si(mole/m3)	0.037697
10	in_NOX-N (mole/l)	0.029175
8	in_PO4-P (mmole/l)	0.022111
9	in_TP (mmole/l)	0.017431

www.waterjpi.eu

BLOOWATER
WP3 Treatment

Pawel Krzeminski, Mohamed Said Lebad, Andreas Ballot, Christian Vogelsang

NIVA

Çağrı Akyol, Giulia Cipolletta, Enrico Marinelli, Anna Laura Eusebi,

Stefania Gorbi, Francesco Fatone

(UNIVPM)

www.waterjpi.eu

Overview on Treatment Goals WP3
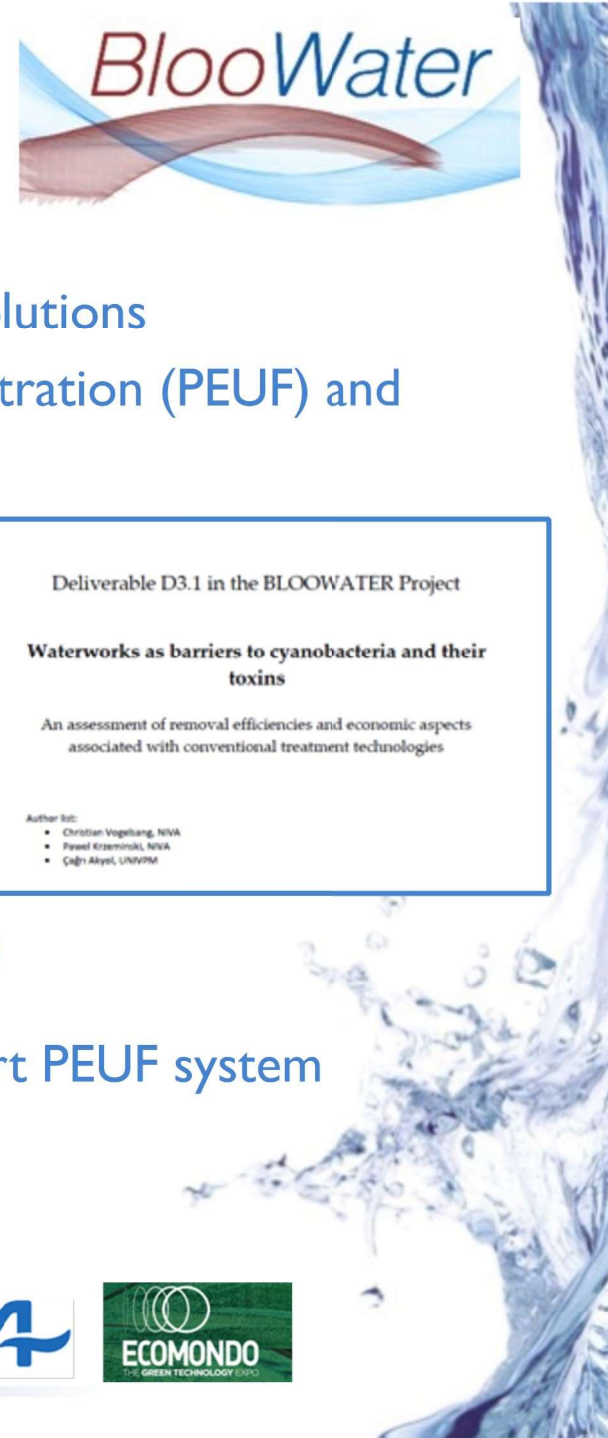
❑ **WP3 Tasks:**

- WP3.1 Definition of specific technological treatment solutions
- WP3.2 Bench scale testing of polymer enhanced ultrafiltration (PEUF) and reference technology
- WP3.3 Processes design, development and validation

❑ **NIVA's tasks:**

- WP3.1 Review conventional treatment
-           technologies targeting cyanotoxins

- WP3.2 Test removal efficiencies of nanofiltration (NF)

- WP3.3 Investigate UF membrane biofouling to support PEUF system development

Deliverable D3.1 in the BLOOWATER Project

Waterworks as barriers to cyanobacteria and their toxins

An assessment of removal efficiencies and economic aspects associated with conventional treatment technologies

Author list:
- Christian Vogelsang, NIVA
- Paweł Krzeminski, NIVA
- Çağrı Akyol, UNIVPM

BlooWater

Table of contents

Updated guidelines from WHO (2021):
Short-term and life-long guideline values for microcystins, cylindrospermopsins, saxitoxins and anatoxins in drinking water

Table 9. *Summary of expected water treatment performance for the removal of selected extracellular cyanotoxins.*

Treatment process	Expected removal based on observed values			Comments
	Microcystins	Anatoxin-a	Cylindrospermopsin	
Slow sand filtration	++/+			
Nanofiltration	+++	(0/++)	++/+++	
Adsorption on activated carbon	++/+++	(+++)	+++	Adsorption varies by carbon type and type of cyanotoxin; competition with NOM
Ozonation (post clarification)	+++	+++	+++	
Free chlorine (post filtration)	+			
Potassium permanganate	++	++	0	Effective on soluble toxin, but only in absence of whole cells

Significant knowledge gaps related to membrane treatment:
- Removal of other cyanotoxins than microcystins
- Effects from shear = release of intracellular cyanotoxins
- Effects of different membrane configurations
- Effects of longer filtration runs; effects from fouling
- Experiments with real raw water

Water JPI

ENEA   UNIVERSITÀ POLITECNICA DELLE MARCHE   NIVA   ECOMONDO

WP 3.2 Test

- ❑ Nanofiltration lab testing goals:
  - effectiveness of (extracellular) toxins removal,
  - impact factors influencing toxin removal,
  - release of cyanotoxins during membrane filtration.

- ❑ But before NF ⇒ some preparatory works:
  - Production of toxin-producing cyanobacteria
  - Optimization of cell lysis to release toxins
  - Setting up ELISA method for toxins quantification

Freeze/thawing

Ultrasonication

Filtration

Centrifugation

Detection

Optimization of cell lysis to release extracellular toxins:

	Microcystins (MC)		Anatoxin (ATX)		Saxitoxins (STX)		Cylindrospermopsin (CYN)	
	Conc. [μg/L]	% change	Conc. [μg/L]	% change	Conc. [μg/L]	% change	Conc. [μg/L]	% change
Freeze/thawing	117	-	28	-	57	-	163	-
Freeze/thawing + sonication*	175	50%	38	33%	70	24%	249	52%
Freeze/thawing + centrifugation	96	-17.7%	32	12.2%	59	3.4%	173	5.8%
Freeze/thawing + filtration 0.7 μm	122	4.5%	28	0.4%	38	-33%	154	-5.5%

* - for different toxins different sonication power was optimal ranging from 0.6-18.5 W/mL

Filtration can remove algae cells (before NF tests) without significantly reducing toxins concentrations

WP 3.2 Test

- Production: toxin concentrations are low (30-160 µg/L)

- Cell lysis method: freeze/thawing followed by sonication
  - toxins concentrations increase by +20-50% (40-250 µg/L)

- Next steps:
  - Waiting for pipette tips (since January) and starting NF tests
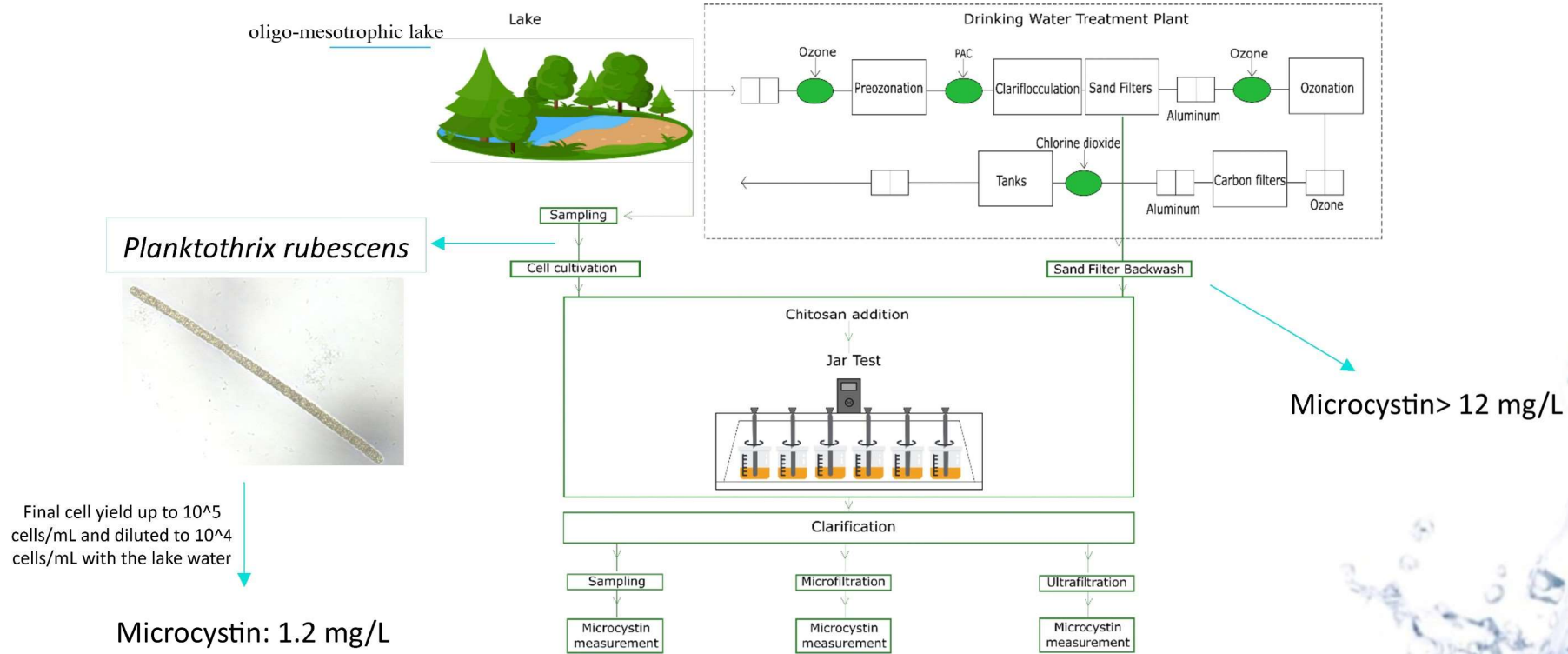
Long channel membrane test cell (LCMTC)

Removal effectiveness & impact factors

UNIVPM TASKS

WP3.2 Bench Scale Testing of PEUF and reference technology

oligo-mesotrophic lake

Planktothrix rubescens

Final cell yield up to 10^5 cells/mL and diluted to 10^4 cells/mL with the lake water

Microcystin: 1.2 mg/L

Microcystin> 12 mg/L

WP3.2 Bench Scale Testing of PEUF and reference technology

1) Characterization of water samples and optimization of chitosan-aided coagulation/flocculation

Parameter	Unit	Lake water	SFBW
pH	-	7.3	7.8
EC	$\mu s/cm^2$	367	485
Alkalinity	$mgCaCO_3/L$	184	185
DO	mg/L	7.6	7.3
Chemical oxygen demand	mg/L	73	124
Total suspended solids	mg/L	5	60
Total dissolved solids	mg/L	680	520
Total phosphorus	mg/L	<0.1	0.3
Nitrate	mg/L	2.89	<0.1
Sulphate	mg/L	57.8	55.4
Chloride	mg/L	18.4	20.7
Sodium	mg/L	15.6	16.5
Potassium	mg/L	2.4	2.6
Magnesium	mg/L	14.3	14.6
Calcium	mg/L	96.8	99.2
Iron	mg/L	0.044	0.169
Copper	mg/L	0.044	0.123
Manganese	mg/L	0.005	0.034
Aluminium	mg/L	0.044	0.202
Zinc	mg/L	0.113	0.558
Barium	mg/L	0.124	0.069
Lead	mg/L	<0.01	<0.01
Chromium	mg/L	<0.001	<0.001
Nickel	mg/L	<0.001	<0.001
Cadmium	mg/L	<0.0004	<0.0004

Test (in duplicates)	Chitosan dose (mg/L)	Rapid mixing Velocity (rpm)	Time (min)	Slow mixing Velocity (rpm)	Time (min)	Sedimentation Time (min)
1	1	100	3	40	30	30
2	1	150	2	40	30	30
3*	1	200	1.5	40	30	30
4	1	250	1.2	40	30	30
5	2	100	3	40	30	30
6	2	150	2	40	30	30
7*	2	200	1.5	40	30	30
8	2	250	1.2	40	30	30
9	3	100	3	40	30	30
10	3	150	2	40	30	30
11	3	200	1.5	40	30	30
12	3	250	1.2	40	30	30
13	4	100	3	40	30	30
14	4	150	2	40	30	30
15**	4	200	1.5	40	30	30
16	4	250	1.2	40	30	30
17	5	100	3	40	30	30
18	5	150	2	40	30	30
19	5	200	1.5	40	30	30
20	5	250	1.2	40	30	30
21	10	100	3	40	30	30
22	10	150	2	40	30	30
23	10	200	1.5	40	30	30
24	10	250	1.2	40	30	30

BlooWater

ENEA   NIVA   ECOMONDO

WP3.2 Bench Scale Testing of PEUF and reference technology

2) Bench-scale PEMF and PEUF experiments of PC and SFBW

At optimal conditions (200rpm rapid mixing for 2 min) using 4 and 20 mg chitosan/L

Coagulation/flocculation/clarification

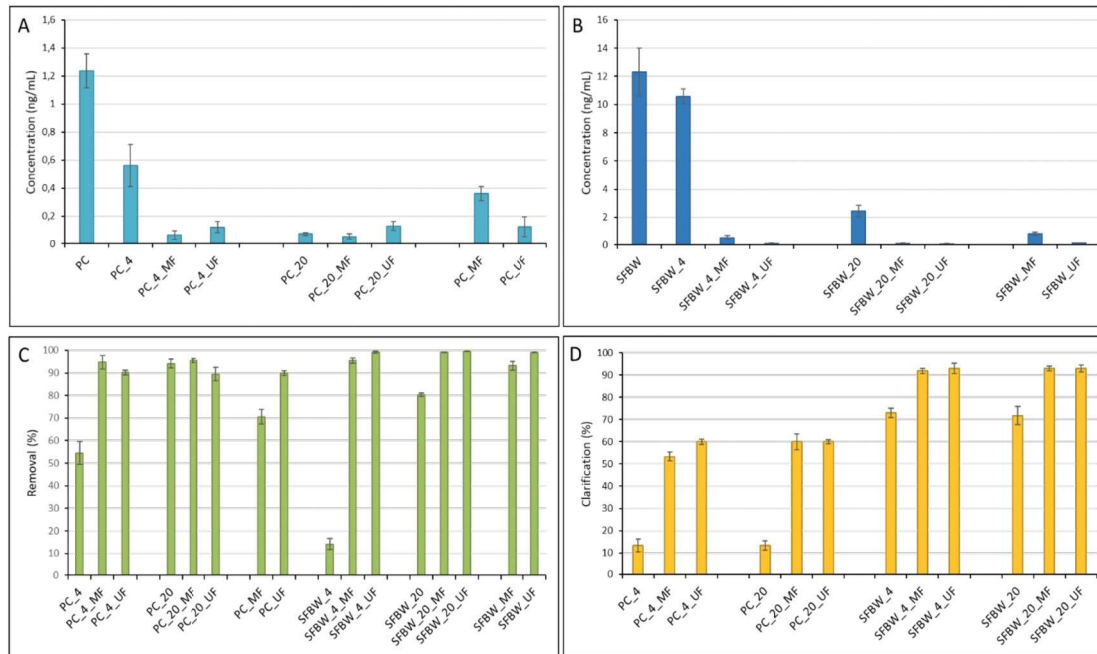Coagulation/flocculation/clarification → MF (fiber membrane filters - 0.45 μm)

Coagulation/flocculation/clarification → UF (Merck Millipore AmiconTM stirred cells - 10 kDa)

Direct MF and UF

WP3.2 Bench Scale Testing of PEUF and reference technology

2) Bench-scale PEMF and PEUF experiments on PC and SFBW

- Microcystin (MC) < 0.15 mg/L in all tests in the final effluents
- 90-95% removal in PC in 4-20 mg chitosan/L in PEMF and PEUF
- >99% removal in SFBW at 20 mg chitosan/L in PEUF
- Low MC → PEMF, high MC → PEUF

PC: *P. rubescens* culture
SFBW: Sand filter backwash water
4: 4 mg chitosan/L
20: 20 mg chitosan/L

WP 3.3 Processes design, development and field validation of the promising water treatment technologies

✓ From the results of the bench activities, the optimal flow scheme is designed and developed by UNIVPM to treat 0.2-0.5 m³/d of surface water.

Sedimentation tank	UdM	Values
Total volume of the reactor	m3	0,67
HRT	h	1,44
Ultra filtration characteristics	UdM	Values
nominal membrane	m²	0,35
nominal pore size	µm	0,01-0,05
Micro filtration characteristics	UdM	Values
nominal membrane	m²	0,07-0,35
nominal pore size	µm	1-2
Specific gas demand	m³/m²h	
Operating parameters	UdM	Values
Treated flow rate range	L/d	180-360
Chitosan dose	mg/L	0-20
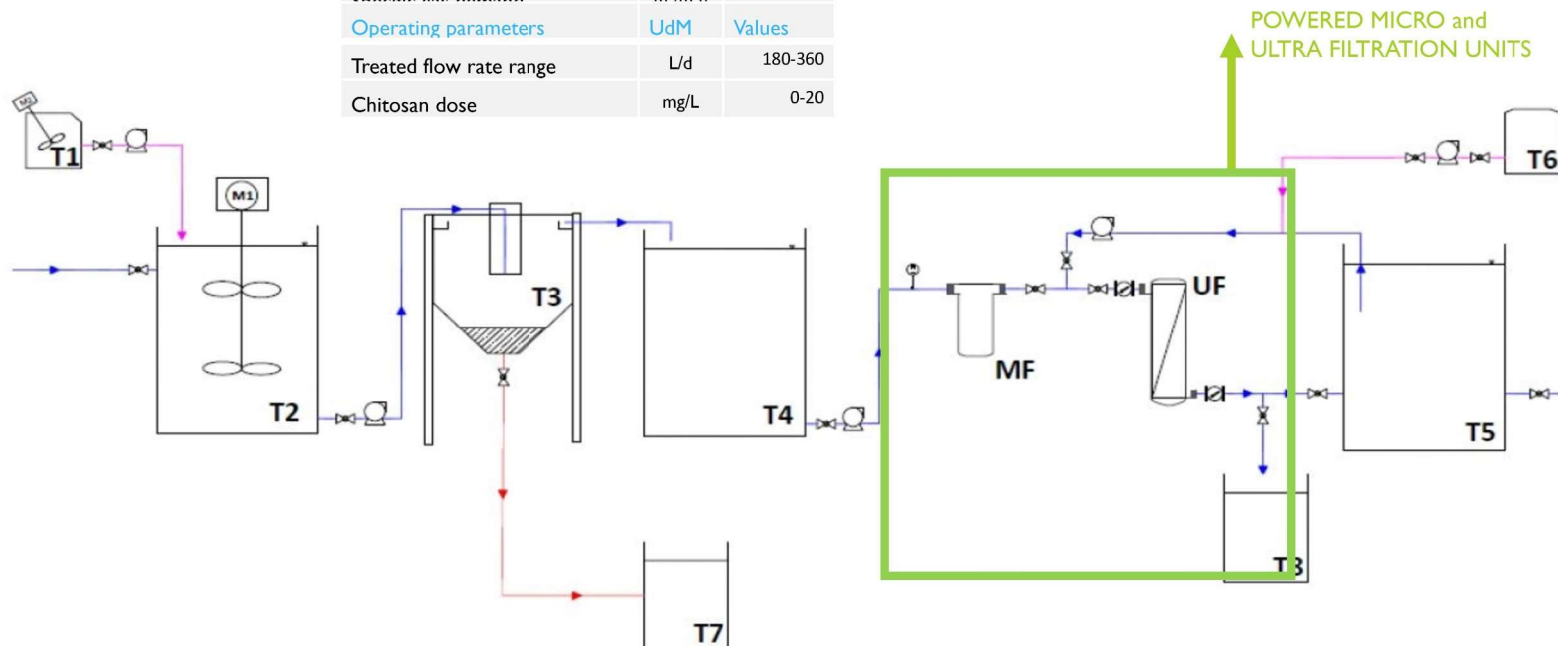
POWERED MICRO and ULTRA FILTRATION UNITS

Monitoring of cyanobacterial blooms and assessing polymer-enhanced microfiltration and ultrafiltration for microcystin removal in an Italian drinking water treatment plant ☆
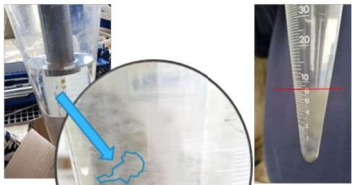
Çağrı Akyol [a], E. Gozde Ozbayram [b] ⚲ ✉, Stefano Accoroni [c, d], Serena Radini [a], Anna Laura Eusebi [a], Stefania Gorbi [c], Carla Vignaroli [c], Simone Bacchiocchi [d], Debora Campacci [d], Fabiola Gigli [e], Giuseppe Farina [e], Meric Albay [b], Francesco Fatone [a]

BlooWater

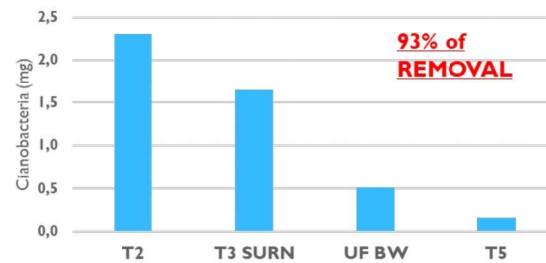# The pilot scale Powered MF+UF for cyanobacteria removal in real environment

► **Lab Scale**

Chitosan dose 20 mg/L

· Pilot Scale

93% of REMOVAL

BlooWater

Plan of experiment

Start	End	Configurations	Sampling Points
02/08/2021	03/08/2021	4 mg/L Chitosan + UF	P1, P2, P3, 2 x P4, P5
03/08/2021	04/08/2021	0 mg/L Chitosan + UF	P1, P2, P3, 2 x P4, P5
04/08/2021	05/08/2021	20 mg/L Chitosan + UF	P1, 2 x P4, P5
03/08/2022	04/08/2022	20 mg/L Chitosano + MF	P1, P2, P3,P4, P5(POST MF)
25/08/2022	01/09/2022	Long term 20 mg/L Chitosano + UF	P1, P2, P3,P4, P5

Results on going

BLOOWATER

Update on WP 4 DSS

ENEA-UNIVPM

Overview on DSS Goals WP 4

Deliverables

M3 A guidelines on data collection and management
M8 A social mapping of the relevant stakeholders and the role
M8 Database set up

The delay accumulated in the first phase of WP1 has also strongly slowed down the activities related to this WP. The Covid emergency has increased the delay especially in the direct exchange with partners.

Priorities

Complete data collection
Database design and development

COLLABORATION and SYNERGIES

- Department of Sciences of University Roma 3 and Department of Applied Geo-informatics and Spatial Planning of Czech University of Life Sciences Prague → remote sensing

- Department of Robotics of Enea→ drone

- Department of Environmental Biology of University La Sapienza of Rome → photogrammetry and image processing applied to bloom

STAKEHOLDER ENGAGEMENT

Regional Agency for Environmental Protection - ARPA Lazio and ARPA Marche- showed interest in the project outputs and collaborated by providing historical data series on the new pilot areas of the project, Lake Albano in Lazio and Lake Castreccioni in Marche;

Regional Park of "Castelli Romani" is strongly interested in monitoring the quality of the lake water; is providing great logistical and administrative support for the necessary authorizations to navigate and fly within protected areas; and above all to extend the activity also in other lakes of the Park interested in the phenomenon of cyanotoxic blooms

Acquambiente, a company totally owned by Local Authorities with a strong vocation in the management of water resources, both in terms of research, water supply, supply and distribution of drinking water and in the collection, treatment and purification of wastewater and wastewater until their return to the natural water bodies; the drinking water treatment plant located in the district of Castreccioni is managed by Acquambiente Marche S.r.l., which is therefore particularly interested in the treatment of waters subject to blooms

The Manifesto of Intent has been signed for a "**Lake Water Contract for Albano, Nemi and for the River Incastro**"

(18-03-2021)   **District Basin Authority of the Central Apennines**

https://www.bloowater.eu