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## Project proposal

# EU PROJECT OF LIFE PROGRAMME "ALGAE SERVICE FOR LIFE" CREATES TOOLS FOR ECOLOGICAL SERVICE TO MITIGATE CYANOBACTERIA AND MACROALGAE BLOOMS IN FRESHWATER ECOSYSTEMS

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**Abstract**

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EU international project of LIFE programme "Algae Service for LIFE" seeks to promote best practices in ecological service and development of circular economy. The goal of the project is to demonstrate integrated efficient management of nutrients and nuisance algal blooms at the catchment scale by harvesting cyanobacteria scums and macroalgae mats in various types of water bodies (rivers, lakes and estuarine lagoon). Also, it seeks to raise awareness of the national and local authorities, business community and society on the environmental, water quality and health hazard issues. The paper provides the idea of applying ecological measures to control algal blooms. Thus, issues related to the causes and mechanisms of eutrophication in inland freshwaters as well as to consequences such as algal blooms are highlighted. The measures proposed in the project are briefly discussed in the light of European Union directives.

**Keywords:** Baltic Sea, cyanotoxins, distant methods, eutrophication, lakes, phytoplankton, river, water quality.

## INTRODUCTION

Due to growing human population, water ecosystems are pushed to challenge with accelerated loading of anthropogenic nitrogen (N) and phosphorus (P) resulting in hypereutrophication (Paerl et al., 2016). Import-driven over-enrichment of nutrients promotes excessive production of autotrophic organisms, and primarily uncontrolled growing algae and cyanobacteria that condition to harmful blooms. In addition, climate change acting together with eutrophication is expected to enhance occurrence and intensity of blooms and make their control even more difficult in the future if the external nutrient loads are not reduced (Rolighed et al., 2016).

Massive growth of macroalgae or cyanobacteria is the first sign that the water body has been affected. Extensive development of macroscopic algae in freshwaters creates the environmental and social problems in aquatic ecosystems due to formation of spatially large mats (Messyasz et al., 2015, 2018). They can choke water body, clog irrigation pipes, block out access of the light to aquatic plants, lead to loss of ecosystem balance and biodiversity. The decaying macroalgae mats cause oxygen depletion in water, promote secondary enrichment with nutrients, and trigger off an offensive smell, when they are washed ashore on the beaches.

Meanwhile, harmful cyanobacteria blooms (HABs) pose even more significant threats to water quality worldwide, because of high risk to human health or biota and also economic losses for recreation, fishery, shipping and the other industry sectors (Kudela et al., 2015; Sanseverino et al., 2017). Cyanobacteria produce high variety of cyanotoxins that can cause skin irritation, seriously harm liver, digestive and nervous systems or even lead to human, wild animal and livestock death (Koreivienė et al., 2014; Meriluoto et al., 2014). Human exposure to cyanotoxins usually occurs through ingestion of contaminated drinking water or food (mainly seafood), use of contaminated water for hemodialysis and during recreational activities. Due to presence of cyanotoxins, 88 human deaths have been reported in Brazil, and nearly hundred human deaths have been attributed to cyanobacteria bloom in Kenya (Sanseverino et al., 2017). Half of the reported episodes of intoxication by cyanotoxins are associated with the risk during bathing and recreational activities. For instance, in UK, the soldiers have been hospitalized with gastrointestinal illness and mucosal membrane blistering after swim-training in the lakes with dense blooms of cyanobacteria (Codd et al., 1999). Moreover, cyanotoxins can be accumulated in the aquatic organisms that become dangerous for human nutrition (Papadimitriou et al., 2009; Paldavičienė et al., 2015). Also, they can accelerate development of various diseases such as cancer, Alzheimer (Stoyneva-Gärtner et al., 2017). Cyanobacterial toxin distribution in Europe and their involvement into poisoning episodes clearly illustrate that water-users and all biota are experiencing serious risk (Mantzouki et al., 2018; Krztoń et al., 2019). Therefore, HABs are one of the major environmental health risks in EU and worldwide (Meriluoto et al., 2017).

In general, eutrophication and harmful blooms are identified as a major water quality management issue that limit water use for drinking, recreation and cause economic losses (Pretty et al., 2015; EPA, 2015). For example, to improve water quality in the Dawesville Channel estuary and to keep beaches clean for the recreational use, the cost of macroalgae harvesting was more than 60 million USD (Water Facts, 1998). Also, during cyanobacteria *Microcystis* bloom in Lake Erie, the estimated cost to ecosystem service interruptions reached 136 million USD (Bingham et al., 2015). Therefore, the aim of the current paper is to disclose the reasons of algal and cyanobacteria proliferations in aquatic ecosystems and discuss measures suitable to apply for mitigation of blooms on catchment scale with a particular focus to the LIFE programme project.

## Eutrophication – a leading cause of algal and cyanobacteria blooms in inland freshwaters and the Baltic Sea

Phosphorus has been recognized as priority nutrient that controls freshwater ecosystem productivity, whereas nitrogen limitation is characterized for brackish waters (Paerl, 2009). Co-stimulating effect of nutrients that accelerate eutrophication and proliferation of HABs on a global scale has been also identified (Elser et al., 2007). Therefore, the balanced control of both nutritional elements can effectively reduce blooms along freshwater-marine continuum and it is highly needed for long-term management of eutrophication in aquatic ecosystems. Moreover, long-term accumulation of nutrients in sediments supports internal loading and defines time lags of ecosystem responses to applied nutrient control measures. So, nutrient inputs from catchment and efficiency of internal nutrient recycling as well as nitrogen and phosphorus transformation into biomass of primary producers are important, when considering the measures for mitigation of eutrophication.

Eutrophication is one of the most important long lasting water quality problems in many aquatic ecosystems in Europe and the Baltic Sea, therefore, much attention is focused towards effective measures to combat this issue. Currently, nutrient emissions from the catchment to rivers and lakes still cause eutrophication problems in inland freshwater ecosystems. Most industries with high-nutrient waste streams (intensive agriculture, mineral processing, energy production and municipal waste) are located around freshwaters (Cole et al., 2014). Nutrient pollution from the point sources has been reduced significantly (up to 18% for N and 23% for P) in the countries after applying EU and national legislation, HELCOM recommendations that contributed to construction of new facilities and the stricter controls on industry and municipal wastewater treatment plants (Combating eutrophication…, 2016). However, diffuse losses from agriculture remain still the most important nutrient source to freshwaters and the Baltic Sea (Wulff et al., 2014; Helcom, 2018). Therefore, the Helcom nutrient reduction scheme that includes Maximum Allowable Inputs (MAI) and Country-Allocated Reduction Targets (CART) for every country member was agreed on in 2007 and updated in 2013 (Bergström et al., 2017). The minimum annual cost to meet Baltic Sea Action Plan (BSAP) for basin targets is estimated to be 4.7 billion EUR (Wulff et al., 2014). Therefore, BSAP requires tools for cost-efficient long-term nutrient abatement. The harvesting of cyanobacteria and macroalgae biomass from aquatic ecosystems can be one of them.

## Tasks and targets of the project "Algae Service for LIFE"

Management of nutrient loads from catchment and mitigation of algal and cyanobacteria blooms in inland water bodies are of crucial importance in order to reduce eutrophication processes in the Baltic Sea. EU project of LIFE programme "Algae Service for LIFE" (Algae – economy-based ecological service of aquatic ecosystems, LIFE17 ENV/LT/000407) focuses on cyanobacteria and macroalgae blooms in lakes, rivers, ponds and the Curonian Lagoon.

Three main project actions deal with bloom mitigation in freshwater ecosystems:

**1)** ***Construction, testing and demonstration of prototypes for harvesting of cyanobacteria and macroalgae***. Harvesting of excessive algal and cyanobacteria biomass was proposed as emergency short-term measure to restore a target water body with acute water quality problems. Mechanical removal of aquatic vegetation and algae is the environment friendly, technically simpler and less expensive *in situ* measure for nutrient control among other suggested solutions (e.g. creating a buffer zone, sediment dredging, application of algaecides) to prevent load of nutrients from agricultural lands into water bodies (Weissteiner et al., 2013; Ibisch et al., 2016; Dondajewska et al., 2019). Prototypes for freshwater wild algal and cyanobacteria biomass harvesting have not been yet widely applied and only a few demonstrative practices usually excluding clear estimation of ecological and economic benefits have been provided worldwide (Adey et al., 1993; Water facts, 1998; Carmichael et al., 2000; Gröndahl, 2009; Pechsiri et al., 2014; Messyasz et al., 2015; Pikosz et al., 2017). Nevertheless, several commercially available mechanical harvesters exist nowadays (Fig. 1), but they are not sufficiently effective or even useless for the collection of special type of macroalgae mats and cyanobacteria scums. Also, the aquatic ecosystems of various type and morphology require different technical solutions to ensure efficient prototype operation and biomass harvesting. Therefore, problem-orientated innovative prototypes for harvesting of algal and cyanobacteria agglomerations and capable to operate in various freshwaters will be manufactured during the "Algae Service for LIFE" project.

Efficiency of algae and cyanobacteria biomass harvesting will be tested for mitigation of blooms in aquatic ecosystems in Lithuania and Poland (Fig. 2). Those water bodies suffer from heavy and recurring cyanobacteria and macroalgae blooms and belong to the risk group ecosystems in the countries (Fig. 3). The selected Lithuanian rivers (Šventoji, Dubysa, Jūra) belong to the River Nemunas watershed that has at least 60% of agricultural land cover. The small rivulet Nielba with over 50% of agrarian land in the catchment belongs to the River Vistula system. The Rivers Nemunas (Lithuania) and Vistula (Poland) are among six largest rivers in the south-eastern part of the Baltic Sea drainage area, where the highest concentrations of nitrogen and phosphorus have been found (Stepanauskas et al., 2002).

**2)** ***Elaboration of the methods for evaluation of cyanobacteria scums, macroalgae mats in situ and water quality analysis using traditional and distant methods***. The European water policy (Marine Strategy Framework Directive, Annex 1, point 5) requests to develop distant methods as a new tool for the monitoring of bloom events in various aquatic ecosystems, because standard hydrobiological methods are time and labour consuming. Satellites, aircraft or other unmanned aerial vehicles (UAV) imaging systems are up-to-date technology, which allows using the light in spectral bands and band ratios in algorithms as modelled pigment indicators. Chloro-

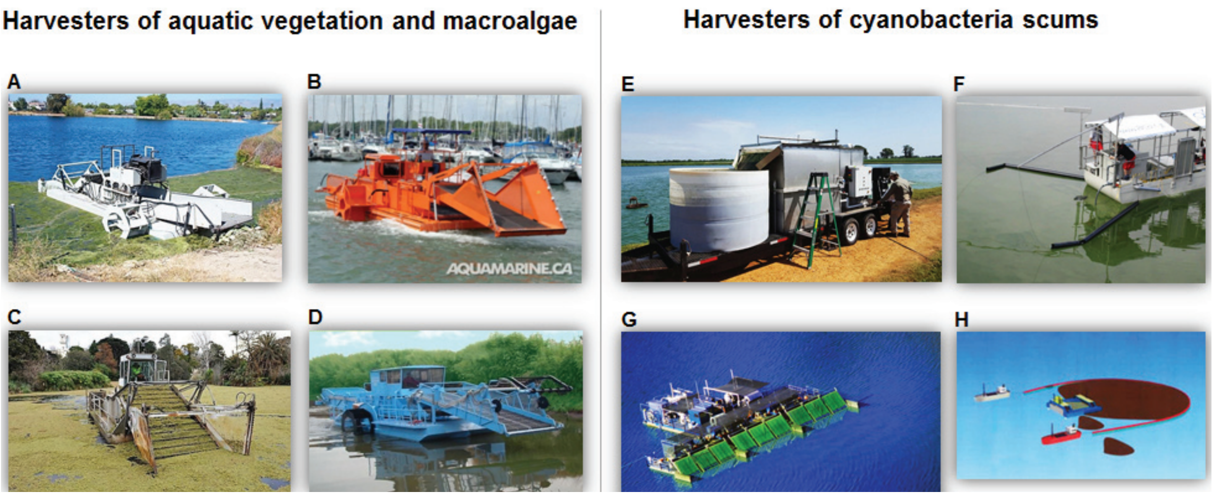


Fig. 1. The examples of manufactured harvesters for collection of aquatic vegetation and macroalgae (A–D) or cyanobacteria scums in small water bodies (E–F) and large water ecosystems (G–H). **A** – Harvester for aquatic vegetation and algae (San Jose, California, USA). https://commons.wikimedia.org/wiki/File:Algae_harvester-2.jpg [Accessed on 20-05-2019]; **B** – H5-200 Aquatic weed harvester Aquamarine H5-200 (Ontario, Canada). www.aquamarine.ca/aquatic-weed-harvesters/ [Accessed on 20-05-2019]; **C** – Azolla harvester (India). www.azollaamrit.com/gallery.php?pid=6 [Accessed on 20-05-2019]; **D** – SINOBE-ACON Automatic Underwater Aquatic Vegetation cutting device (China). 803768290/Specially_Designed_Automatic_Underwater_Aquatic_Vegetation_Harvester_For_Sale.html [Accessed on 20-05-2019]; **E** – ALGENT – mobile cyanobacteria harvesting platform (USA). www.smithsonianmag.com/innovation/startup-harvesting-wild-algae-make-your-next-pair-sneakers-180960872/ [Accessed on 20-05-2019]; **F** – ASIO – vessel for cyanobacteria harvesting (Czech Republic) www.asio.cz/en/vessel-for-the-separation-of-biomass-particles [Accessed on 20-05-2019]; **G** – *Aphanizomenon flos-aquae* scum harvester from Lake Klamath (USA). https://cerulequebecfr.com/tag/algue-klamath/ [Accessed on 20-05-2019]; **H** – modified oil boom device for harvesting cyanobacteria scums in the Baltic Sea, Sweden (Gröndahl, 2009)


Fig. 2. Location of aquatic ecosystems selected for the harvesting of algal and cyanobacteria agglomerations during the project "Algae Service for LIFE" implementation

phyll *a* is used as proxy for phytoplankton biomass and phycocyanin – as cyanobacteria biomass marker. Moreover, occurrence of the hot-spots of algae and cyanobacteria agglomerations for most efficient biomass harvesting are hardly predictable due to water body peculiarities, its catchment characteristics, and variation in the environmental factors (seasonal timing, temperature, wind direction). Distant methods can increase the economic feasibility of harvesting and allow quickly define the target location of algal and cyanobacteria agglomerations and the best period for biomass collection with minor time input. Satellite images have already been proposed for monitoring of large water ecosystems (Varunan & Shanmugam, 2017), also for the Curonian Lagoon (Bresciani et al., 2014). However, they are not suitable for bloom monitoring in small water bodies. Although satellites nowadays provide high resolution images, price is too high to use them for cyanobacteria and algae harvesting in small water bodies. Therefore, UAV was selected as the best alternative for the methodology


Fig. 3. Cyanobacteria and macroalgae blooms in Lithuanian and Polish water bodies

in small freshwaters. For this reason, the multidisciplinary approach to detect blooms through the combined use of the data received *in situ* and from remote sensing tools will be applied. In the project, we seek: i) to demonstrate suitability of distant methods to increase economic feasibility of algal harvesting; ii) to develop new methodology for bloom monitoring in inland small water ecosystems based on UAV images.

**3)** ***Raise awareness on environmental and social problems related to algal and cyanobacteria blooms at national and international levels.*** Action seeks to raise awareness to the environmental, water quality and health hazard issues related to nutrient input to ecosystems and hazardous cyanotoxins among the national and local authorities, the business community and society for the continuation and transfer of application of the proposed measures on a broader scale. The aim, activities, results and other related information for the general public and stakeholders are provided on the website, Facebook and ResearchGate profile of the project. Training seminars that include lectures, demonstration of the harvester operation and distant methods for algal agglomeration survey is expected to engage policy makers and relevant stakeholders (e.g. representatives of governmental institutions, regional and local authorities as well as administrations of protected areas). Considering an EU perspective with the aim to communicate and present the idea of the project, the results and outcomes will be distributed by direct communication and through different social networks, conferences.

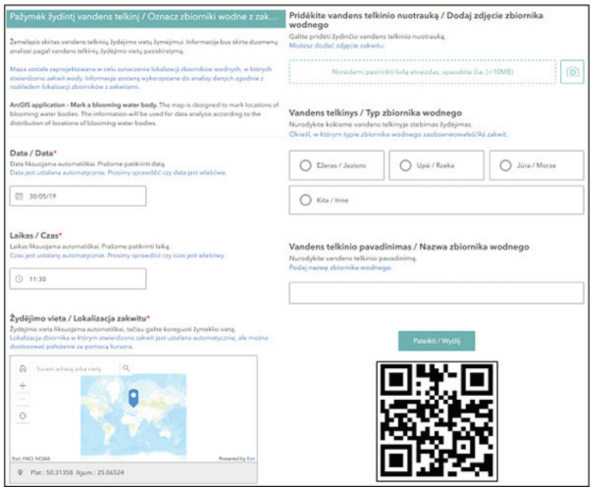


Fig. 4. The questionnaire "Mark a blooming water body"

The ArcGIS application "Mark a blooming water body" with on-line questionnaire is available on the project website (http://algaeservice.gamtostyrimai.lt/) and via Quick Response code (Fig. 4). The map is designed to mark locations of blooming water bodies. The information will be used for data analysis according to the distribution of locations of blooming water bodies. The state institutions and society were invited to take part with the contribution to provide relevant information and register hot-spots of the blooming water bodies to the database.

## EU Directives dealing with algal and cyanobacteria bloom issue

To achieve the goals of EU Directives related to the water quality (Water Framework Directive 2000/60/EC, Marine Strategy Framework Directive 2008/56/EC, Bathing Waters Directive 2006/7/EC, Nitrates Directive 91/676/EEC), the project addresses integrated management of nutrient inputs and organic pollution of agricultural origin, and suggests measures on river basin or catchment scale. Removal of nutrients by using "natural-like" processes contributes to the "EU Strategy for the Baltic Sea Region" and provides an integrated framework for improvement of the environmental conditions in the Baltic Sea. The project pursues to promote ecosystem-based approach to control harmful blooms in inland waters and to diminish nutrient loads to the Baltic Sea from the catchments. It is intended to develop the technologies for the provision of water service and gently mitigation of eutrophication.

By implementing **Water Framework Directive** (2000/60/EC), the project seeks to remove algae and cyanobacteria that rapidly assimilate nutrients and this way to reduce contamination of surface waters with phosphorus and nitrogen compounds, to improve water quality and preserve biodiversity. Proposed harvesters are the instrument to control diffuse pollution from the catchment to inland waters and from lake sediments. Under the **Marine Strategy Framework Directive** (2008/56/EC), Member States ensure to reach good state and high biodiversity of the marine environment by 2020. The harvesting of excess phytoplankton agglomerations in the Curonian Lagoon and macroalgae collection in the selected rivers of the Nemunas basin will contribute to the reduction of nutrient transit to the Baltic Sea and to improvement of the water quality on catchment scale.

Following **Nitrates Directive** (91/676/EEC), the project seeks to eliminate nitrogen compounds assimilated into harvested biomass and to block their flow further through the waterways. **Bathing Water Directive** (2006/7/EC) is focused on water quality, monitoring of algae (cyanobacteria) blooms, and mitigation of their risks. Cyanobacteria species can produce severe toxic compounds that create health hazard to humans and biota. Therefore, special attention in the project is devoted to mitigation of harmful blooms and protection of bathing water quality. Proposed harvesting of cyanobacteria scums will secure inland aquatic ecosystems relevant for recreation and fishery. **Drinking Water Directive** (98/83/EC) seeks to protect human health by ensuring that drinking water is safe for consumption (does not contain poisoning microorganisms or substances). World Health Organization Guidelines for Drinking water quality recommend provisional value of 1 µg/mL for MC-LR (cyanotoxin produced by cyanobacteria).

International team members, focusing on the current ecological issues of the environment and skilled in different technical-applied solutions jointly carry out the project. The project is implemented by research institutes of the Nature Research Centre (LT) as a coordinating beneficiary, Adam Mickiewicz University in Poznan (PL) and the Institute of Nature Conservation, Polish Academy of Sciences (PL). Also, the business companies the Baltic Environment (LT) and Spila (LT) and the non-governmental organization the Nature Heritage Fund (LT) are involved in the project implementation.

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# ES LIFE PROGRAMOS „ALGAE SERVICE FOR LIFE“ PROJEKTAS, SKIRTAS SUKURTI PRIEMONES IR PASLAUGAS SUMAŽINTI MELSVABAKTERIŲ IR MAKRODUMBLIŲ „ŽYDĖJIMUS“ GĖLAVANDENĖSE EKOSISTEMOSE

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## Santrauka

Europos Sąjungos LIFE programos projektas „Algae Service for LIFE“ skatina gerąją ekologinių paslaugų praktiką ir žiedinės ekonomikos kūrimą. Projekto tikslas yra demonstruoti integruotą efektyvų maistinių medžiagų ir dumblių „žydėjimų“ valdymą upių baseinų lygyje, surenkant perteklinę melsvabakterių ir makrodumblių biomasę iš skirtingų vandens telkinių (upių, ežerų, tvenkinių, Kuršių marių). Taip pat projektu siekiama skleisti informaciją nacionalinėms ir vietos valdžios institucijoms, verslo bendruomenei bei didinti visuomenės susidomėjimą vandens telkinių ekologine būkle. Straipsnyje aptariamos ekologinės vandens „žydėjimų“ kontrolės priemonės ir paslaugos, akcentuojant gėlavandenių ekosistemų eutrofikacijos ir „žydėjimų“ priežastis ir pasekmes. Siūlomos projekte priemonės prisideda prie Europos Sąjungos strateginių direktyvų įgyvendinimo.