SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA17133
STSM title: Examining sorption and metabolization potential of phosphorus and nitrogen from brackish open water bodies with nature based solutions
STSM start and end date: 01/06/2021 to 30/07/2021 (Extended to 06/08/2021)
Grantee name: Ece Kendir Cakmak

PURPOSE OF THE STSM:

Eutrophication is one of the major global problems for marine ecosystems causing undesirable effects such as loss of biodiversity, toxic algal blooms, and creating dead zones. Nitrogen and phosphorus are the primary nutrients responsible for triggering the eutrophication problem, whereas wastewater discharge, agricultural runoff as well as atmospheric depositon are possible sources for nutrient accumulation in the marine environment. Nutrient reduction from these sources is one of the possible solutions to prevent marine eutrophication. Furthermore, in-situ/ex-situ treatment strategies for eutrophic marine waters are also needed to provide a more effective solution for the eutrophication problem, especially in terms of already accumulated nutrients in the sediments and water body. In this respect, nature-based technologies have an outstanding potential within the context of sustainability, circularity and cost-efficiency.

This STSM aimed to investigate phosphorus and nitrogen removal of eutrophic brackish water (Baltic Sea) using lab-scale systems mimicking conditions in the envisioned vertECO© raft nature-based technology. It also aimed to theoretically investigate possible phosphorus utilization pathways (such as co-composting) and to assist with the conceptualisation of the envisioned full-scale vertECO© raft.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

The experiments were conducted at the premises of alchemia-nova (Austria) in open-air conditions (i.e. no controlled environment) to re-create as realistic conditions as possible. The brackish water was collected from the Stockholm archipelago, Baltic Sea and transported to alchemia-nova prior to the STSM. Totally, 7 systems were constructed to run triplicates of two different treatments using different plants and a control system without plants. The systems were fed from a submerged pump in a 250L feeding tank with an even distrubiton system. The systems consisted of horizontally placed plastic columns (inner diameter:15 cm, height: 1 m, total volume: 18 L) filled with substrate mix and cut open on top to be equipped with/without plants, an outlet pipe to control water level, buckets for outlet water collection and outlet volume measurements. The buckets were covered with polyethylene covers to prevent contamination and dillution by rainfall. The plastic columns were filled with a substrate mixture containing zeolites, pumice, and biochar (mixing ratio of 30:60:10) (Figure 1). Smaller zeolites (≈1 cm Ø) were put in the substrate mix and bigger zeolites (1.5-2.5 cm Ø) were used at the inlet&outlet at 5 cm length of each system for better distribution, reducing clogging risks at the inlet, and better outlet drainage. Mesh material was used to prevent outlet pipe clogging. The plants (5 bunches for each system) were planted on the 29th June and given an establishment period before experiments. Selected plants were *Schoenoplectus tabernaemontani* (Plant A) and *Bolboschoenus maritimus* (Plant B),chosen for being adapted to brackish water conditions and domestic in the Baltic Sea region. Prior to the planting, the earth around plant roots was removed and washed off with water to prevent possible nutrient release. The final configuration is depicted in Figure 2. During the establishment phase, systems were fed for 20 days with artificial sea water (6 psu salinity, 0.55 mg/L NO_3-N, 0.06 mg/L PO_4 and 0.03 mg/L NH_4^+-N) that simulates real Baltic Sea water. Finally, artifical sea water was adjusted to higher eutrophic conditions by adding phosphate and ammonium salts (0.831 mg/L PO_4^{3-} and 1.968 mg/L NH_4^+-N) to mimic bottom water from a real eutrophic bay stated in Rydin et al. (2017)[1]. The systems were fed with this water for 5 days. During establishment phase, hydraulics of the systems were also tested. After the establishment phase, real Baltic sea water (adjusted to higher eutophic conditions as stated above also for artificial water) was introduced. Every two days, samples were collected from the effluent buckets. Inlet and outlet samples were analysed in terms of NH_4^+, NO_3-N, NO_2-N, PO_4^{3-},pH, and electrical conductivity. pH and electrical conductivity were measured with a WTW pH/cond 3320. The nutrients were analysed with Hach Lange reagents and a portable spectrophotometer (DR1900). Plant growth was visually monitored thoughout the experiments.

Figure 1. Substrates used in the experiment

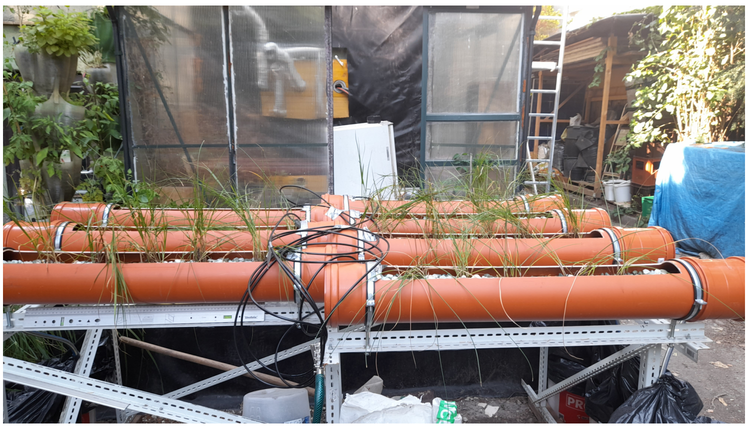

Figure 2. The lab-scale vertECO© raft system used in the experiment

1 Emil Rydin, Linda Kumblad, Fredrik Wulff, and Per Larsson *Environmental Science & Technology* **2017** *51* (8), 4559-4566.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The experiments with the real sea water lasted for 9 days. The average initial nutrient concentrations of the water were amounted to 0.875 mg/L PO_4^{3-} , 2.675 mg/L $NH4^+$, 0.55 mg/L NO_3-N and 0.006 mg/L NO_2-N. The removal efficiencies for $NH4^+$ and PO_4^{3-} are shown in Table 1. $NH4^+$ was removed effectively with both treatments and the control. The maximum efficiency was achieved by Plant B, *Bolboschoenus maritimus*, with up to 99.9% (effluent concentration < 0.01 mg/L). The average removal efficiency of plant A, *Schoenoplectus tabernaemontani,* was lower than *Bolboschoenus maritimus*. The relatively high average $NH4^+$ removal in control system (no plants) indicates a high removal by the substrate mixture itself. Hence, the contribution of the plants on $NH4^+$ removal efficiency was positive but at a smaller extent. The removal of PO_4^{3-} for the control achieved a maximum removal of 57%. The contribution of *Bolboschoenus maritimus* to the removal was positive with a maximum removal of 63%. *Schoenoplectus tabernaemontani* showed removal efficiencies similar as the control treatment. For all configurations, PO_4^{3-} removal efficiencies decreased after 4 days which could be due to occupation of the adsorption sites. For instance, the lowest effluent concentrations in the treatment with Plant B amounted to 0.32 mg/L PO_4^{3-} after 4 days and and increased to 0.54 mg/L PO_4^{3-} after 9 days.

Table 1. Removal efficiencies of the lab-scale vertECO© raft systems

Removal efficiency (%)	**$NH4^+$**	**$PO4^{3-}$**
Control (without plants)	Min-max*:87-94% Average**:90.0±2.9%	Min-max:28-57% Average:35.5±18.7%
Schoenoplectus tabernaemontani (Plant A)	Min-max:89-97% Average:91.6±3.3%	Min-max:29-33% Average: 35.9±16.7%
Bolboschoenus maritimus (Plant B)	Min-max:97-99.9% Average:98.6 ±1.2%	Min-max:39-63% Average: 54.6±10.2%

*: Minimum and maximum removal efficiencies (%) throughout the experiment as average
**: Average removal efficiency with std(%) through the experiment

NO_3-N outlet concentrations decreased for all systems during the first 4 days of analysis and later they increased. After 9 days, the outlet NO_3-N concentration for control and treatment with Plant A was 1.8 mg/L. Treatment with Plant B showed lower outlet concentration than others with 0.6 mg/L NO_3-N after 9 days. Changes in NO_2-N outlet concentrations were as 0.015-0.022 mg/L for control , 0.01-0.04 mg/L with Plant B and 0.03-0.14 mg/L with Plant A. pH values increased during the passage through the systems which could be due to the zeolites which might have increased pH of the water. The initial pH value was 8.07 and final pH values were as 8.55-8.73. Electrical conductivity of the water was initally 10.55 mS/cm and final values were 9.38-9.79 mS/cm. In conclusion, Plant B,*Bolboschoenus maritimus* showed better performance than Plant A, *Schoenoplectus tabernaemontani* and control in terms of nutrient treatment. However, the effect of plants with respect to substrate effects was comparatively low. Apart from outlet water characteristics, the plants were also monitored visually whereas the height of the plants increased during experiments. Growing of new shoots was also observed and the growth was better for Plant B *Bolboschoenus maritimus*. For valorization of nutrient storage in the plants or substrate mix, the potential pathways will be discussed later.

FUTURE COLLABORATIONS (if applicable)

This STSM showed a successful collaboration between the involving institutions that provided an initial step for further collaborations. Regarding the findings of this STSM, the system has a potential for real-scale applications. Hence, future collaborations between these institutions will include improving the current vertECO© raft system design and commercialization. The grantee also gained a great experience and knowledge of nature-based systems in general. The STSM provided a different perspective for eutrophic water treatment to the grantee. Apart from potential future collaborations and experiences gained through STSM, the findings of this STSM are planned to be submitted in a journal and/or presented in a conference. KTH and alchemia-nova have also been working jointly on a review paper related to phosphorus recovery strategies for eutrophic marine environment to be submitted soon.