H2O SCITECH
WATER INSTITUTE

GlobalGiving

Plant filter islands: final report

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Social and educational project: **Plant filter islands**

Equality and social impact on the environment

Funding

GlobalGiving

Implementation

H2O SCITECH
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Project partners

3M Science. Applied to Life.

Państwowe Gospodarstwo Wodne Wody Polskie

Participants

Liceum Ogólnokształcące nr V

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Szkoła Podstawowa nr 7 im. rtm. Witolda Pileckiego we Wrocławiu

H2O SCITECH – WATER INSTITUTE

The H2O SCITECH – WATER INSTITUTE Foundation was established in 2019 in Wrocław. The Foundation's aim is to independently and continuously conduct basic research, industrial research, and experimental development work, as well as to widely disseminate the results of such activities through education, publication, and knowledge transfer.

The Foundation's mission is to educate and promote science among children, youth, and adults, with a focus on the preservation of our planet's water resources. The Foundation focuses on scientific research and the development of new water filtration technologies.

Plant filter islands

Plant filter islands are a natural method for water purification. The island consists of carefully selected filtering plants attached to a buoyant raft. These floating islands act as phytoremediators, „extracting” pollutants from the water, which are then trapped in the plant tissues.

The project's goal was to engage the local community, non-governmental organizations, and companies in environmental protection efforts, particularly encouraging the residents of Wrocław to take actions that improve the state of water bodies. The project is an example of a grassroots initiative demonstrating integration and equality across communities and generations in addressing the issue of water pollution, including that of the Oder River, on which Wrocław is located.

Plant filter islands: final report

Roślinne wyspy filtracyjne: raport końcowy

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Content

Fig. 1. Plant filter islands launched on the Oder River (source: H2O SCITECH)

Summary

ASSUMPTIONS

Plant filter islands are a simple nature-based solution that can be used for water purification. In the project, the construction of the islands served as a form of community engagement and provided a space for „learning through experience."

RESULTS

The planned tasks were appropriately tailored to the profile of the workshop participants. The filter islands did not maintain buoyancy throughout the entire growing season, which required additional intervention; however, the developed concept proved successful in other aspects.

LESSONS

Planning the work requires due diligence to avoid any inconsistencies in the ecological message. Building the islands using organic materials is feasible, but additional buoyancy elements should be applied to ensure prolonged flotation. Filter islands planted with diverse species purify the water and create new habitats within the ecosystem. Arranging the islands in series parallel to the shore is a beneficial solution; shallow waterways with gentle flow can support the durability of the rafts and the effectiveness of the plants. Cleaning larger rivers may involve placing the islands in their smaller tributaries. Efforts should be made to increase the scope of tasks performed by project participants while providing support and developing feedback collection methods, such as „brainstorming".

NEXT STEPS

The developed concepts will enable the implementation of similar projects outside urban centers: in small towns and agricultural areas, where water pollution by nutrients is a significant problem. Some elements of the islands will be reused to test their durability. Recommendations based on the project's results will be tested in practice.

Introduction

Water pollution problem

The ecological disaster on the Oder River in 2022 highlighted the alarming state of our rivers. The direct cause of the mass fish die-off was toxins released by the algae species *Prymnesium parvum* (commonly known as „golden algae"). The phenomenon of algal blooms occurs under stress factors, which in this case were increased water salinity associated with low water levels (a decrease in the amount of solvent increases the concentration of dissolved substances) and pollution by nutrients[1].

Nutrient pollutants – compounds that cause the eutrophication of surface waters and contribute to the excessive growth of expansive organisms (including phytoplankton)[2].

The most problematic nutrients include nitrogen and phosphorus compounds. Nitrates and phosphates, as substances contributing to eutrophication, are listed in Annex VIII of the *Water Framework Directive*, which specifies the most significant water pollutants[3].

It is estimated that while in developing countries, water pollution results from improper management of domestic sewage, in highly developed countries, most pollution is leached from agricultural

[1] E. Nachlik et al., *Zarządzanie wodą w sytuacjach kryzysowych*, Fundacja Gospodarki i Administracji Publicznej 2023, p. 10-11.

[2] E. Jachniak, *Związki biogenne, a proces eutrofizacji wód Goczałkowickiego Zbiornika Wodnego*, „Infrastruktura i Ekologia Terenów Wiejskich" no. 3(3)/2013, p. 33-34.

[3] *Dyrektywa 2000/60/WE Parlamentu Europejskiego i Rady z dnia 23 października 2000 r. ustanawiająca ramy wspólnotowego działania w dziedzinie polityki wodnej*, p. 342.

areas[4] (point sources, such as livestock buildings; non-point sources, such as intensively fertilized fields)[5].

Anthropogenically accelerated eutrophication leads to numerous phenomena detrimental to ecosystem stability, including:

- excessive growth of phytoplankton biomass;
- development of algal bloom species;
- changes in the species composition of higher plants;
- reduction of dissolved oxygen levels in the water;
- decrease in water transparency[6].

The reduction of nutrient pollution at the source of the problem can be achieved by introducing specific practices in agricultural production. An example is *Ecological Recycling Agriculture* (ERA), a system of organic farming proposed within the *Baltic Ecological Recycling Agriculture and Society* (BERAS) project, which assumes the integration of crop and livestock production within single or nearby farms. This allows for the return of nutrients taken up by feed plant biomass back into the soil and promotes the even distribution of livestock farming in the geographical area, which consequently reduces the saturation of the soil with nitrates and phosphates and the leaching of these compounds into surface waters[7].

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[4] *The United Nations world water development report 2024: water for prosperity and peace*, UNESCO 2024, p. 1.

[5] C. Jasiewicz, A. Baran, *Rolnicze źródła zanieczyszczenia wód – biogeny*, „Journal of Elementology" no. 11(3)/2006, p. 370-373.

[6] M. Dokulil, K. Teubner, *Eutrophication and climate change: present situation and future scenarios*, w: *Eutrophication: causes, consequences and control*, Springer 2011, s. 2-6.

[7]A. Granstedt i in., *Ecological recycling agriculture to reduce nutrient pollution to the Baltic Sea*, „Biological Agriculture and Horticulture" no. 26(3)/2008, p. 296-299.

Capturing the already existing excess of nutrients requires a different approach. Nature-based solutions are gaining increasing popularity – utilizing the capabilities of natural elements to restore and maintain balance in the environment. These include artificial wetlands and buffer strips of vegetation, among others[8].

Plant filter islands

Plant filter islands are also a nature-based solution, commonly referred to as floating treatment wetlands. In this case, the phytoremediation capabilities of aquatic and wetland plants are utilized, growing on a raft structure floating on the water's surface. The exposed roots of the plants are submerged in the water column, where they directly absorb nutrients and pollutants, incorporating them into their own biomass, which can then be easily removed from the reservoir or watercourse[9].

Phytoremediation – the use of plants selected for their ability to absorb, degrade, or immobilize specific undesirable substances for environmental remediation[10].

Phytoremediators used for planting filter islands can absorb not only nutrients from the water but also heavy metals[11], which are

[8] A. Rizzo et al., *Nature-based solutions for nutrient pollution control in European agricultural regions: a literature review*, „Ecological Engineering" no. 186/2023, p. 1-2.

[9] H. Keizer-Vlek et al., *The contribution of plant uptake to nutrient removal by floating treatment wetlands*, „Ecological Engineering" no. 73/2014, p. 684-685.

[10] M. Siwek, *Biologiczne metody oczyszczania środowiska – fitoremediacja*, „Wiadomości Botaniczne" no. 52(1/2)/2008, p. 23-26.

[11] R. Sharma et al., *Application of floating treatment wetlands for stormwater runoff: a critical review of the recent developments with emphasis on heavy metals and nutrient removal*, „Science of the Total Environment" no. 777/2021, p. 8-10.

a significant issue, especially in rivers that run through industrialized and urbanized areas for long stretches[12].

The advantages of plant filter islands include their suitability for locations characterized by variable water levels, as well as the low labor requirements needed for construction and maintenance; the islands also provide additional benefits in terms of increased biodiversity and habitat availability in anthropogenic ecosystems[13].

The ease of implementation combined with clear effectiveness makes plant filter islands the core of projects with various purposes and scales. Islands placed in wastewater reservoirs can significantly improve their properties and allow for reuse in agriculture[14]. Meanwhile, small structures made from recycled materials can be applied in gardens and individual farms[15].

In the project presented in this report, plant filter islands – as well as the process of construction, monitoring, and analysis of their potential – were used to promote knowledge about natural solutions in ecological engineering among the local community.

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[12] D. Ciszewski, *Wpływ regulacji koryta Odry na akumulację osadów zanieczyszczonych metalami ciężkimi: zróżnicowanie, zmiany w czasie, zagrożenie środowiskowe*, „Studia Naturae" no. 52/2006, p. 5.

[13] H. Keizer-Vlek et al., *op cit.*, p. 684.

[14] M. Afzal et al., *Floating treatment wetlands as a suitable option for large-scale wastewater treatment*, „Nature Sustainability" no. 2/2019, p. 863-871.

[15]A. Kietla et al., *Pływające wyspy*, Łódź Art Center, p. 1-35.

The need for environmental education

A significant portion of Poles express concerns about the state of the natural environment, although these concerns more frequently focus on the global scale rather than the local one. A strong majority of respondents (70%) report being very or highly concerned about the state of the environment worldwide, while 53% express the same level of concern at the national level. However, only one in four respondents (25%) worry about the environmental condition in their own locality[16].

Research and observations from the Water Institute's social initiatives, meetings, and environmental education campaigns reveal that public awareness and knowledge about the state of the environment and climate change are minimal – at best, they remain very general and often derive from media slogans rather than reliable data and scientific sources that explain causes and propose specific solutions. Alarmingly, studies on participation in ecological activities and efforts to promote behavioral change show even worse results. There is a lack of engagement in initiatives that could contribute to halting the global trend of environmental degradation

The implementation of the „Plant filter islands" project demonstrated that younger individuals and residents of larger cities are more likely to adopt a positive approach toward ecological actions and the implementation of effective solutions. However, belief in individual agency to address global climate problems remains very low.

The difference in levels of environmental awareness and engagement often correlates with economic status, education level, and place of residence. For example, concern about the

[16] *Świadomość ekologiczna Polaków*, „Komunikat z badań CBOS" no. 163/2020, p. 1.

local environment is more prevalent among urban residents, with every second resident of major metropolitan areas expressing high or very high concern, compared to just 14% of rural inhabitants. Similar trends appear when examining concerns at the national or global levels, though the disparities are less pronounced. Additionally, the level of concern across all scales – local, national, and global – tends to be higher among respondents with better education[17].

These findings unequivocally highlight the importance of knowledge and the need for ongoing education to raise awareness and foster action for environmental improvement.

The findings of the *Report on the awareness and environmental behaviors of Polish citizens* show that:

> the issue of environmental protection saw the largest decline in priority compared to 2020, dropping by 28% to just 24%. Current threats, such as those arising from political crises, have relegated environmental issues to a lower priority. The most pressing environmental problems are air pollution, waste management, water contamination, and limited water resources[18].

The state of the natural environment should remain an integral part of every global citizen's consciousness, with efforts spanning individual, local, national, and international levels. Regardless of political or economic circumstances, environmental care and plans to counter threats must feature prominently in climate policy and the concerns of every citizen.

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[17] *Ibidem*, p. 3.

[18] *Raport z badania świadomości i zachowań ekologicznych mieszkańców Polski 2022*, *Streszczenie zarządcze*, Ministerstwo Klimatu i Środowiska 2022, p. 2

A crucial element in achieving this is education – environmental education at every level, including in the home, schools, and workplaces. Such education should be implemented through the education system, non-governmental organizations, and institutions supported by local and national governments. Alongside systemic solutions and national, European, and global legislation, grassroots initiatives and social campaigns play an essential role in increasing ecological knowledge and fostering engagement. Every effort to disseminate knowledge and promote environmentally friendly practices contributes to safeguarding health and the environment.

The *Report on environmental awareness* reveals that the most frequently cited reasons Poles wish to protect the environment are concern for future generations and human health. Respondents believe that the state of the environment primarily depends on individual activity (62%), followed by effective legal regulations (36%) and societal recognition of environmental issues as significant problems (33%)[19].

Social activism, educational programs, and intergenerational and cross-community knowledge-sharing proved effective in the „Plant filter islands" project. The focus on environmental education and the protection of water quality engaged communities in addressing local issues, increasing knowledge and awareness, and boosting confidence in the impact of grassroots actions.

The involvement of diverse groups – including primary school students, youth, adults, local residents, scientific representatives, the socially engaged company 3M, and the State Water Holding „Polish Waters" – enabled social integration and the development

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[19] *Ibidem*, p. 2.

of effective solutions for purifying rivers and water bodies, which could be scaled up.

Environmental education is fundamental to ensuring equality and the efficacy of society in efforts to protect the natural environment and achieve climate safety.

Each individual bears personal responsibility for shaping ecological attitudes and behaviors.

Concept

Plant filter islands consist of several key elements that determine their properties and effectiveness:

- Raft – a platform floating on the water's surface, providing space for plant growth;
- Plants – aquatic or wetland species that are well adapted to the conditions of the selected reservoir or watercourse and are characterized by their ability to accumulate pollutants;
- Substrate – organic material, present in small quantities, that allows plants to establish roots;
- Anchoring elements – enable the secure mooring of the islands in the chosen location and their modular connection.

In designing the islands, it was assumed that the raft should be constructed as much as possible from biodegradable materials while maintaining buoyancy with a minimal amount of additional floats. Its dimensions should allow for easy manual handling. The materials used must be durable enough to prevent the island from breaking apart before the end of the growing season.

The main part of the raft was made from willow fascine, which has low density in its dry state. The structure was connected using alder beams – a species characterized by high durability when fully submerged in water.

It was decided to use more than one species of plants for the plantings in order to maintain diversity and visual appeal of the installation. The selected plant species should be characterized by their tolerance to complete submersion of the root system and water flow, which are conditions present in the Oder River. Initially, based on a literature review, eight plant species were selected to assess their suitability in the final stage of the project:

- yellow flag iris (*Iris pseudacorus*),
- water mint (*Mentha aquatica*),
- bulrush (*Schoenoplectus lacustris*),
- narrow-leaved cattail (*Typha angustifolia*),
- needle spike-rush (*Eleocharis acicularis*),
- soft rush (*Juncus effusus*),
- sweet flag (*Acorus calamus*),
- common reed (*Phragmites australis*).

For planting the plants, a peat substrate was chosen – deacidified and free of fertilizers that could leach into the water – along with biodegradable fabric bags.

Main assumptions: biodegradable materials, compact format, diverse species, inert substrate, durable anchoring elements made of metal and plastics.

Due to the nature of the river and the fact that it serves as a navigation channel, it was necessary to choose durable and highly visible mooring elements. For this reason, it was decided to use components made of plastic and stainless or galvanized steel:

- polypropylene rope (12 mm thickness),
- concrete anchors (15 kg),

- mooring buoys (10 kg buoyancy),
- threaded rods, nuts, and washers (Ø 10 mm),
- carabiners and shackles for line mounting,
- anchors with a round eye (length 50 cm).

Fig. 2. Prototype raft – element of the plant filter island (source: H2O SCITECH)

Using the described criteria and selected materials, a prototype raft was constructed, which was then trial-launched to test its buoyancy. At this stage, the chosen solutions met the project's needs, and it was decided to replicate the model during the educational workshops.

Implementation

Problem identification

FIRST HALF OF APRIL

On April 11, 2024, the first design workshop took place, aimed at examining water pollution in the Oder River and attempting to select suitable species of filter plants.

Initially, the most common causes of poor water quality were discussed. Algal blooms, whose toxins cause mass fish die-offs and the decline of other organisms, are becoming increasingly frequent in the waters of Polish rivers. The main cause of these blooms is high salinity, which further increases during periods of low water levels, along with the presence of biogenic substances and other pollutants.

Water samples for testing were taken from various stretches of the Oder (oxbow lakes, channels, and freely flowing river sections); to illustrate the variability of biogenic substances, tap water and water collected from an aquaponic system were also prepared[20].

During the workshop, five teams were formed. Each team's task was to examine one of the prepared samples in terms of:

- pH,
- salinity (electrical conductivity, EC),
- phosphate concentration (PO_4^{3-}),
- ammonium ion concentration (NH_4^+),
- nitrate concentration (NO_3^-).

[20] The aquaponic system combines plant and animal production. The substances generated in the water from animal waste and food scraps are utilized in the process of growing edible plants.

Based on the obtained results, the water quality from each location was assessed, and explanations for the observed differences were proposed. Each team, using the provided materials, selected plant species best suited for growth under the analyzed conditions.

Fig. 3. Workshop participants during water analysis (source: H2O SCITECH)

Construction of the islands

MIDDLE OF MAY

During the second workshop meeting, which took place on May 16, 2024, the construction of rafts was carried out, serving as the main element necessary for building filter islands. The following materials were used for this purpose:

- willow fascines (approx. 1.3 m long),
- alder beams (1.5 m long),

– sets of screws,

– mooring ropes,

– jute twine,

– basic tools: a drill with a bit, wrenches, and scissors.

Fig. 4. Process of rafts construction (source: H2O SCITECH)

Each team was tasked, according to previously established instructions, with constructing their own raft. Three holes were drilled into each of the four alder beams, where screws were placed. Then, using these sets, two parallel edges of the raft made from bundles of fascines were clamped together; the central screws were connected with a rope featuring two loops, allowing for subsequent series connection of the islands.

The rafts constructed in this way were marked and assembled near the launch site.

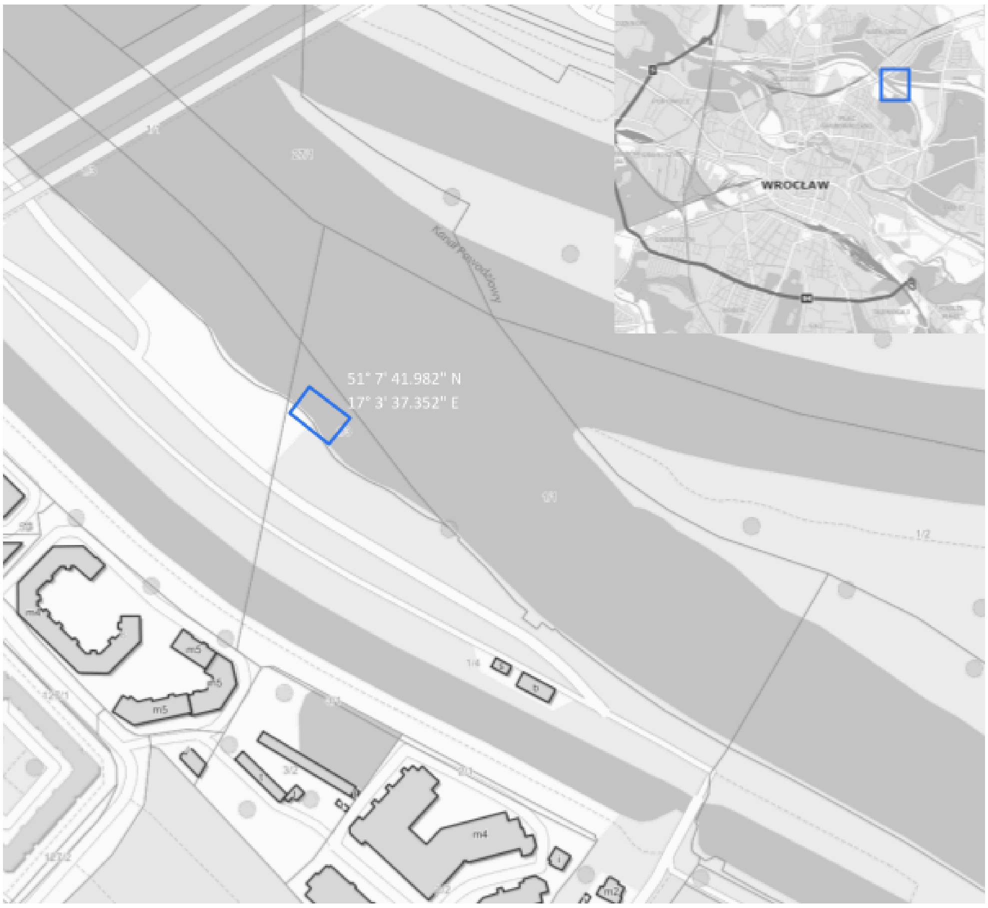

Fig. 5. The launch site for the plant filter islands (source: H2O SCITECH)

Planting

SECOND HALF OF MAY

On May 18, 2024, the final meeting related to the construction of the filter islands took place at the later launch site. Each team found the raft they had constructed and then was tasked with placing the prepared plants into it.

Participants selected the proportions of each species according to their own ideas and the knowledge gained during the first workshops.

Fig. 6. Participants of the project are placing plants in the rafts (source: H2O SCITECH)

Each raft contained 30 to 50 seedlings. The plants were planted in biodegradable fabric bags filled with peat substrate, which were then tied with a piece of jute string. The resulting „pouches" were inserted into the spaces within the bundles of willow branches, spaced approximately 30 cm apart.

The planting process went smoothly, and the proposed method allowed for the plants to be securely integrated into the structure of the rafts. However, it was a mistake to use peat substrate – participants noted that it is not a sustainably sourced material, as its resources do not renew in a short period. This situation indicates not only the need for a change in solution but also the high ecological awareness of the individuals involved in the project.

The deacidified peat used in the planting process should be replaced with materials based on by-products, such as coconut fiber substrate, which do not require the exploitation of natural sites.

Launching and mooring

SECOND HALF OF MAY

After planting, the islands were launched.

Three anchors were placed on the riverbed, connected by a rope to warning orange buoys, which were also moored to the anchors on the bank. The distance between the buoys was chosen to be a multiple of the length of a single island.

The islands were placed one after another on the water and then towed to the designated location, where they were connected in series using carabiners and secured to the prepared buoys.

Fig. 7. Connecting and mooring (source: H2O SCITECH)

Ultimately, the islands formed a row parallel to the riverbank, held in place by the anchors. They were left in this arrangement until the end of the growing season.

Fig. 8. Islands after being launched in the designated location (source: H2O SCITECH)

Monitoring

Acclimatization of plants

BEGINNING OF JUNE

From the time of launching to the harvesting of the plant filter islands, regular monitoring and photographic documentation were conducted.

In the first few weeks, a gradual acclimatization of the plants was observed. The rafts floated just below the water surface, creating optimal conditions for their growth. The seedlings initially rooted themselves in the small amount of available substrate, later drawing nutrients directly from the flowing water.

Fig. 9. Acclimatization of plants in the first days of June (source: H2O SCITECH)

Fig. 10. Pollutants flowing towards the islands (source: H2O SCITECH)

Simultaneously with the early growth of the plants, it was observed that the linear arrangement of the islands, parallel to the river bank, creates a corridor towards which organic pollutants flow.

Rapid growth

END OF JUNE

After successful acclimatization, the plants began to grow vigorously and filled the free spaces within the raft. The root zone of the plants was constantly submerged in water, where the continuous flow ensured the availability of oxygen.

The noticeable increase in biomass indicated that, barring any significant disturbances, the plants would reach their natural form and size before the end of the growing season.

Fig. 11. Visible increase of biomass (source: H2O SCITECH)

At this stage, it was possible to distinguish all eight planted taxa – all the plants had adapted to the conditions present in the Oder. The individual filter islands differed in their species composition, which resulted from the choices made by the builders as well as the varying degrees of species expansiveness. This created a mosaic effect greater than that observed in the natural communities found along the riverbank.

Loss of buoyancy

BEGINNING OF JULY

At the beginning of July 2024, the islands sank suddenly. Initially, it was believed that this was caused by the too-short ropes connecting the islands to the anchors, which meant they would remain below the water's surface in the event of a sudden rise in water levels.

Fig. 12. After the islands sank, only the tallest plants were visible (source: H2O SCITECH)

After verifying the fluctuations in water levels over the preceding days, which did not exceed 30-40 cm, the team approached the mooring site of the islands and found that, despite the available slack in the ropes, they were lying on the riverbed. The islands had spontaneously lost buoyancy, likely due to the gradual degradation and saturation of the willow fascines.

The sinking of the islands occurred when the mass of rapidly growing plants exceeded the buoyancy of the water-saturated fascines due to gradual biodegradation.

Thanks to the presence of mooring lines, it was possible to retrieve the islands. Each raft was equipped with an individual buoy attached diagonally to the top beams, allowing the plants to be raised above the water surface.

Fig. 13. Islands equipped with individual buoys (source: H2O SCITECH)

Fig. 14. Slow regrowth of the more resilient plant species (source: H2O SCITECH)

After the intervention, the plants began to regenerate and resumed growth, which was much slower than in the initial period after launching. The die-off of needle spike rush and soft rush was observed, while significant biomass growth was evident only in the most resilient species (yellow iris and common reed).

Emergency collection

MID-SEPTEMBER

Initially, the collection of the islands was scheduled for September 17, 2024, to allow time for analyses and project summarization before its completion. According to the plan, the islands – detached one by one – were to be pulled to the shore using a pontoon and then transported to the laboratory for plant sorting and preparation for analysis.

On September 15, 2024, the project team received information from the State Water Management Authority regarding the planned opening of the Psie Pole weir, associated with an upcoming flood wave on the Oder River[21]. As anticipated, the opening of the weir and the sudden rise in water levels were expected to result in increased flow intensity and flooding of the so-called floodplain. In response to this announcement, a decision was made on the same day to conduct an early, emergency collection of the islands.

Due to the hydrological conditions, it was not possible to use a pontoon, and the islands were pulled in using the ropes connecting them to the shore. This method ensured the safety of the workers; however, the plants sustained additional damage during the movement of the islands through the shoreline vegetation.

Fig. 15. Filter islands during increased water level (source: H2O SCITECH)

[21] *Informacja o sytuacji hydrologiczno-meteorologicznej w Polsce z dn. 15 września 2024 r.*, Państwowe Gospodarstwo Wodne Wody Polskie 2024, p. 1-4.

Fig. 16. Emergency collection of plant filter islands (source: H2O SCITECH)

Results and conclusions

During the project, in addition to the continuous monitoring of the functioning of the filtration islands, physicochemical analyses of the water collected near the mooring site were conducted to determine the average levels of selected pollutants. After the collection, chemical analyses of the plant material were also performed, allowing for the assessment of the effectiveness of the proposed solution and the development of recommendations for future applications. The results of educational and social tasks were evaluated through a survey that assessed the level of engagement and satisfaction of the workshop participants.

Water analysis

Water for physicochemical analyses was collected three times (in May, June, and July) as a grab sample. The analyses were conducted by the Water Institute and in an external laboratory.

The water exhibited relatively high pH, electrical conductivity (EC), and salinity (S):

$$\overline{pH} = 8,44;$$

$$\overline{EC} = 1,31\ mS \cdot cm^{-1};$$

$$\overline{S} = 1,33‰.$$

No significant contamination with heavy metals was observed – the concentrations of chromium, lead, cadmium, zinc, and nickel were lower than the limit of the analytical method's range. The average concentrations of copper (Cu) and arsenic (As) were respectively:

$$0,0037\ mg\ Cu \cdot L^{-1},$$

$$2,4\ mg\ As \cdot L^{-1}.$$

Among the nutrient compounds in the water, no detectable amounts of ammonia and nitrites were recorded. The average concentrations of nitrate ions (NO_3^-) and orthophosphate ions (PO_4^{3-}) were respectively:

$$8,21\ mg\ NO_3^- \cdot L^{-1},$$

$$0,54\ mg\ PO_4^{3-} \cdot L^{-1}.$$

The limit values for lowland river waters are up to 2,2 mg N-NO3 · L^{-1}, which corresponds to approximately 9,7 mg NO^{3-} · L^{-1}, and up to 0,12 mg P-PO^{4} · L^{-1}, which corresponds to approximately 0,37 mg PO_4^{3-} · L^{-1}. This indicates that the nitrate content approached the permissible value for this quality class, while the orthophosphate content significantly exceeded it[22].

The water was characterized by high pH and electrical conductivity. No significant concentrations of heavy metals were found. The nitrate content was close to the limit value for lowland river waters, while the orthophosphate content exceeded the norm for this class.

Assessment of design solutions

During the presence of the plant filter islands on the Oder, variable meteorological (including storms with heavy rain and hail) and hydrological conditions were observed; there were also extreme events such as increased water levels and flow before the arrival of a flood wave. These factors subjected both the rafts and the plants to numerous challenges, allowing for an assessment of the adequacy of the applied solutions.

The anticipated result of the main assumption – primarily using biodegradable materials – was a reduced durability of the structure compared to commercial solutions. The rafts were constructed using willow fascines, which have a low dry density compared to other native wood species. The low density of the wood provided good initial buoyancy; however, its instability led to gradual soaking, resulting in a loss of buoyancy and the sinking of the islands due to the weight of the plants. The other

[22] *Rozporządzenie Ministra Infrastruktury z dnia 25 czerwca 2021 r. w sprawie klasyfikacji stanu ekologicznego, potencjału ekologicznego i stanu chemicznego oraz sposobu klasyfikacji stanu jednolitych części wód powierzchniowych, a także środowiskowych norm jakości dla substancji priorytetowych*, s. 41-62.

properties of the fascine made it suitable for the construction of the rafts: the building process was easy and quick, and the spaces within the bundles facilitated efficient planting and subsequent plant growth.

Fig. 17. The condition of the alder wood and screws after the collection of the islands (source: H2O SCITECH)

Alder wood beams were used to connect the bundles of fascines, as they are inexpensive, relatively lightweight, and resistant to permanent immersion in water. After the collection of the islands, signs of wood decay were observed in the cross-section of the beams, but it would still be possible to reuse them.

To ensure the buoyancy of the fascine rafts throughout the growing season, it is necessary to use individual buoys. The durability and strength of the selected organic materials allow for their reuse in the construction of the filter islands.

Galvanized steel screws underwent significant corrosion due to contact with water. This complicates the dismantling of the rafts and may lead to the release of zinc. The amount of zinc that potentially entered the Odra River does not significantly affect water quality; however, it is advisable to avoid using numerous metal components containing this element, especially in water bodies with a small volume.

Biomass and species composition

The collected plant biomass was negatively affected by the sinking of the islands (which resulted in the loss of two species and the death of the organs of the remaining plants) and the emergency collection. The total fresh mass of the recovered plants was only 2,9 kg, of which just over 0,6 kg was dry mass. Knowing the natural sizes of the utilized plant species and comparing the number of planted and collected plants, it was estimated that 10-20% of the biomass that could have been obtained in the absence of significant growth disturbances was collected.

Among the collected plants, six species were identified, with the largest mass contribution coming from: yellow iris, common cattail, narrow-leaved bulrush, and common reed. These species were considered the best adapted to deep flowing waters and relatively resistant to temporary flooding. Their intense growth served as an additional factor limiting the development of the remaining species.

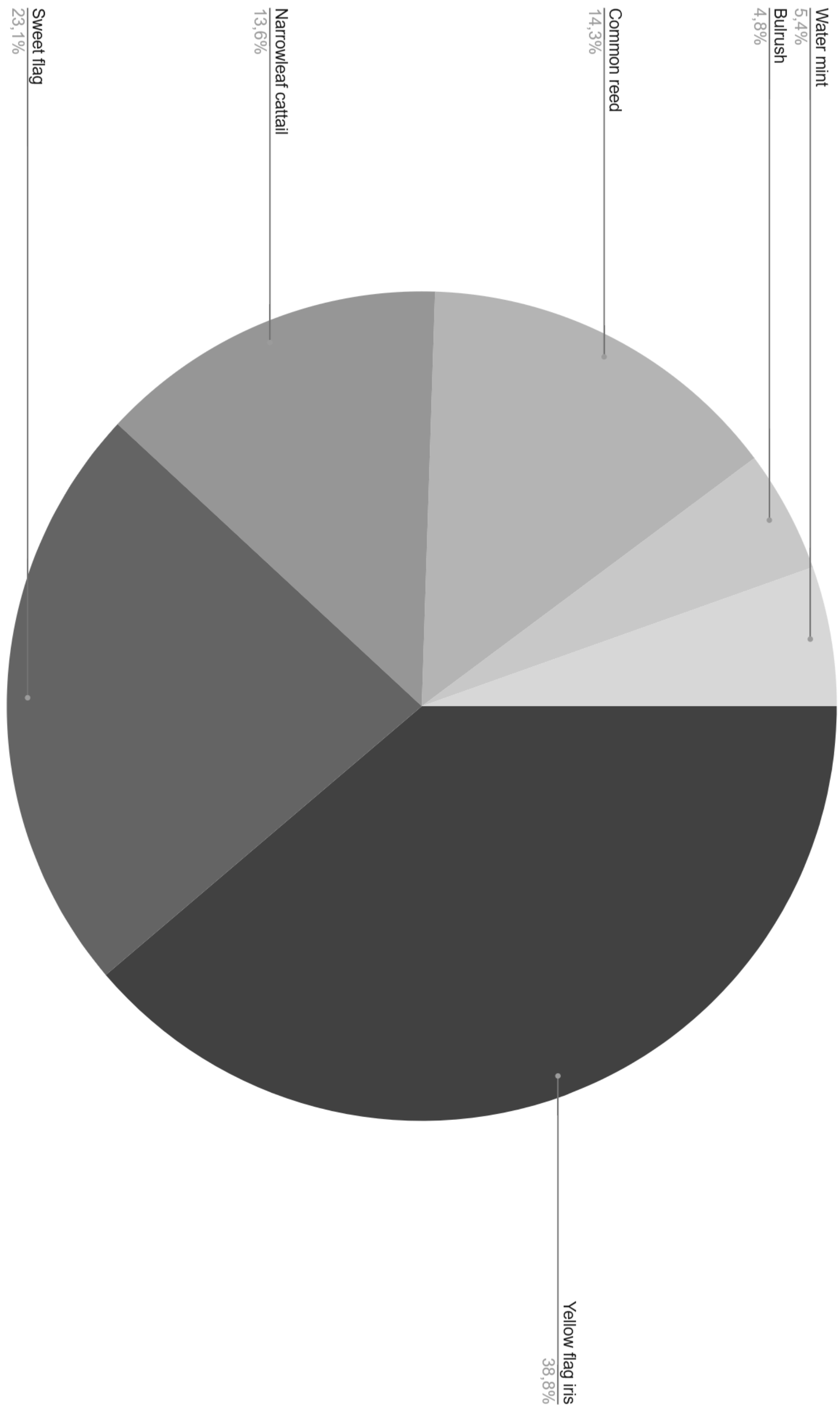

Fig. 18. The proportion of individual species in the biomass (source: H2O SCITECH)

The ability to absorb nutrient pollutants

Due to the absence of detectable amounts of heavy metals in the water and the limited size of samples, it was decided to measure only the total phosphorus and total nitrogen content in the plant material. It was assumed that all phosphorus present in the plant tissues comes from phosphates, and nitrogen from nitrates – the dominant forms of these elements in river water.

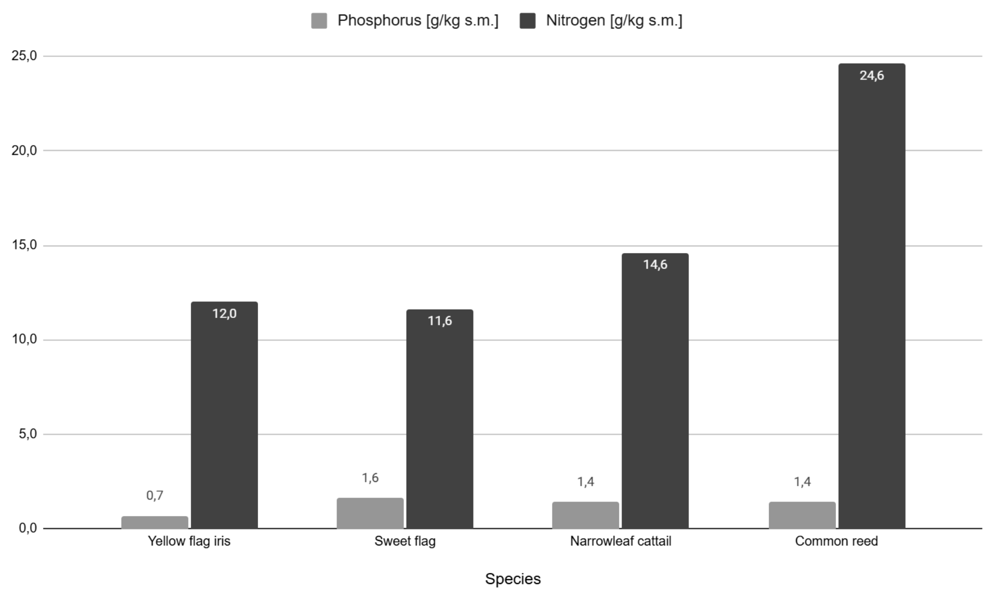

Fig. 19. Content of phosphorus and nitrogen per unit of dry mass (source: H2O SCITECH)

Chemical analyses of the plants were conducted by species to demonstrate differences in the ability to uptake nutrients. The highest amount of phosphorus per unit of dry mass was found in the sweet flag sample, while the greatest proportion of nitrogen compounds relative to mass was absorbed by the common reed.

Throughout the entire growing season, the largest total amount of phosphorus was associated with the biomass of the sweet flag; however, the most nitrogen was captured by the yellow iris, which exhibited more intense growth compared to the common reed.

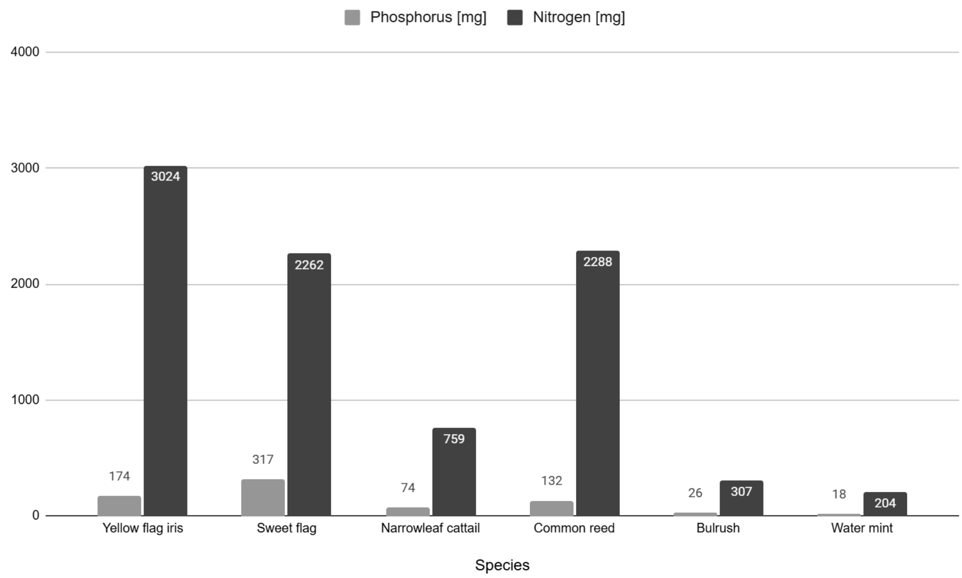

Fig. 20. Total amount of nitrogen and phosphorus associated with the biomass of individual species (source: H2O SCITECH)

The effectiveness of water purification depends on the ability of individual species to absorb biogens and the amount of biomass produced. Overall, the highest amounts of nitrogen and phosphorus were captured by the yellow iris and the sweet flag, respectively.

Effectiveness of filter islands

Four plant species exhibited the best adaptation to growth on filtration islands and the highest effectiveness in purification. Further simplification of the species composition would be inconsistent with the concept of introducing biodiversity into urbanized areas. For this reason, the complex effectiveness of the filtration islands was also analyzed as a comprehensive and mosaic installation.

Knowing the amount of nitrogen and phosphorus absorbed by individual species and the proportion of these species in the total biomass, the total quantity of elements captured by the plants from the five filtration islands was calculated.

NITRATES	PHOSPHATES
total of 8844 mg captured	total of 742 mg captured

Assuming that the main sources of nitrogen and phosphorus were nitrates and phosphates, and knowing the average concentration of these compounds in the water, the potential amount of fully purified water was estimated.

NITRATES	PHOSPHATES
4720 L of purified water	4241 L of purified water

As previously mentioned, the plants produced up to 20% of the maximum biomass achievable with the enhanced design, under favorable conditions. The amount of purified water increases proportionally to the biomass. This means that if the full potential of the installation consisting of five filtration islands were realized, it could extract up to 45 g of nitrates and up to 4 g of phosphates from the water. Knowledge of these values allows for relatively accurate calculations of the surface area of the islands necessary to purify standing water bodies and provides an approximate estimate of the area of islands placed in flowing waters. A strategy worth developing could be the intermediate purification of larger rivers using filtration islands located in smaller tributaries. This approach brings the point of mooring closer to the source of contamination, and shallower water facilitates work and creates favorable conditions for plant growth.

In addition to water remediation, the filtration islands serve to support biodiversity in human-transformed environments. The mix of plant species not only increases ecosystem diversity but also, in conjunction with natural materials, creates new habitats for animals (e.g., river mussels, small fish, crustaceans, birds) and supports the development of beneficial microflora.

Fig. 21. Raft inhabited by numerous mussels (source: H2O SCITECH)

Effectiveness of educational activities

In the opinion of the project team, workshop participants handled the prepared tasks very well. All work was completed within the planned time without making significant mistakes.

During the summary meeting, a simple survey was conducted (table 1) to check whether the knowledge about the proposed solutions had been effectively communicated and to assess the level of satisfaction with participating in the workshops.

96% of respondents could name at least one species of the plants used and mention at least one function of the islands. Knowledge of the islands' functions was somewhat lower among primary school students; secondary school students often indicated several functions along with detailed descriptions. The greatest difficulty for respondents was providing the correct names of the materials used to construct the rafts.

One secondary school student admitted that working in a group was challenging, indicating that educational events should consciously incorporate elements that build soft skills. Among primary school students, only one person reported a difficulty, which was understanding the chemistry topics discussed during the first workshops.

All surveyed individuals expressed a willingness to engage in social activities aimed at solving local problems. The average satisfaction rating for participation in the project was 4,7 (on a 5-point scale), with primary school students rating their satisfaction the lowest (an average of 4,4) and adults the highest (an average of 5,0). With age, the willingness to express criticism decreases; even though the surveys were anonymous, adults feared offending the organizers by not giving the highest rating. Students from both types of schools more often gave a rating of

4,0, but they did not take the opportunity to describe their comments in the accompanying open-ended question.

Both the reluctance to give low ratings and the lack of justification limit the ability to improve future projects. It is important to seek activation methods, such as „brainstorming”, which create a relaxed space for participants to present ideas and can be used by organizers to understand the respondents' opinions on the proposed solutions.

Fig. 22. Summary meeting of the project results (source: H2O SCITECH)

Tab. 1. Summary of the survey among project participants

Individuals demonstrating knowledge of at least one material used in the rafts [%]	
Primary school students	67
Secondary school students	86
Adults	100
In total	83
Individuals demonstrating knowledge of at least one species of the plants used [%]	
Primary school students	100
Secondary school students	93
Adults	100
In total	96
Individuals demonstrating knowledge of at least one function of the filter islands [%]	
Primary school students	83
Secondary school students	100
Adults	100
In total	96
Indicated difficulties	
Primary school students	*chemistry topics* (1 answer)
Secondary school students	*necessity of working in a group* (1 answer)
Individuals expressing a willingness to engage in solving local problems [%]	
In total	100
Average satisfaction rating for participation in the project [on a scale of 5°]	
Primary school students	4,4
Secondary school students	4,6
Adults	5,0
Average in total	4,7

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