Evaluating the nutrient removal efficiency of biochar in a small stream- A case study of Västankvarn farm

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Abstract

The study evaluated the nutrient removal efficiency of a two-stage biochar filtration in an agricultural stream at Västankvarn Gård in Finland. The removal efficiency was calculated as the total nitrogen(TN) and total phosphorus(TP) removal through adsorption by biochar. The system consisted of a sac biochar filter placed across the stream and a downstream box biochar filter. Water samples were collected once every two weeks over a four-month period and analyzed for TN and TP. The results showed extremely high nutrient loads throughout the monitoring period. Statistical analysis indicated no significant difference between influent and effluent concentrations for either nutrient, demonstrating that the biochar filters did not achieve measurable nutrient reduction. Factors contributing to the poor performance included extremely high nutrient concentrations, limited water–biochar contact, sediment clogging, rapid flow-through, and the use of unmodified biochar. A moderate correlation between streamflow and nutrient concentrations showed that both high-flow events and continuous agricultural inputs influence water quality. Although the system was ineffective in nutrient removal, the study provides an important foundation for future field research. The findings suggest that integrated treatment approaches and continuous monitoring are essential for managing nutrient pollution in agricultural streams that ultimately discharge into the Baltic Sea.

Language: English
Key Words: Nutrient removal efficiency, Total Nitrogen, Total Phosphorus,

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1 Introduction

Aquatic ecosystems are important for biodiversity and ecological balance. However, they are increasingly threatened by nutrient runoff, especially nitrogen and phosphorus from agricultural lands and cities. These nutrients enter nearby water bodies, causing pollution and harmful algal blooms that damage ecosystems. (European Court of Auditors, n.d.)

Nutrient runoff comes from many scattered sources rather than a single source. Hence, it is not easy to monitor and regulate. However, several methods exist that can help reduce nutrients in water, such as wetlands and buffer zones alongside the waterways, which act as filters between farmland and water. (Wang et al., 2024)

Small agricultural streams are important pathways that carry nutrients from farmland to larger water bodies, like the Baltic Sea. Nutrient transport in these streams depends on farming practices, rainfall, and streamflow conditions.(Nutrients | US EPA, 2015)

1.1 Nutrient pollution in the Baltic Sea

The Baltic Sea has a cool and wet (boreal) climate and covers a large area of about 415,000 km². Its catchment area is around 1.64 million km². The sea is shallow and has year-round thermal stratification, which makes it vulnerable to eutrophication. Combating eutrophication in the Baltic Sea has received more focused effort and ongoing research than in any other coastal region worldwide. (Finland, 2025)

Eutrophication promotes the growth of algae. Hence, it causes an increase in water turbidity and depletes oxygen conditions at the seabed. When algae die, they release more phosphorus to the bottom, a process known as internal loading, which reinforces eutrophication. If nutrient runoff is not managed properly, the condition of the Baltic Sea will continue to worsen, leading to even more severe ecological damage.

In Finland, nutrients enter the Baltic Sea from various sources, including agriculture, forestry, rainwater, and scattered settlements . Agriculture accounts for more than half of the human-made nutrients entering the Baltic Sea from Finland. Forestry accounts for one-third of the phosphorus and about one-quarter of the nitrogen load to the Baltic Sea. This comes mainly from peatland drainage, soil disturbance, and fertilization. ("Sources of Nutrient Runoff," 2023)

The regional framework for addressing nutrient pollution in the Baltic Sea is coordinated by the Helsinki Commission (HELCOM). HELCOM operates under the Convention on the Protection of the Marine Environment of the Baltic Sea Area. This convention requires member countries to prevent marine pollution and restore ecological balance. In 2007, HELCOM adopted the Baltic Sea Action Plan (BSAP) with the goal of eliminating eutrophication by 2021. The plan established maximum allowable nutrient inputs and national reduction targets for nitrogen and phosphorus. The BSAP was updated in 2021 to include measures addressing biodiversity, eutrophication, hazardous substances, and sea-based activities.

At the EU level, the Marine Strategy Framework Directive requires Member States to achieve Good Environmental Status in marine waters. Supporting directives such as the Water Framework Directive and Nitrates Directive guide national efforts to reduce nutrients from agriculture and wastewater. Baltic Sea countries implement national action programs to meet these commitments through concrete measures, including improved agricultural practices and wastewater treatment.

Nutrient removal technologies play a vital role in improving water quality. These technologies protect aquatic life from harmful nutrients and pollutants, such as Phosphorus (P), nitrogen (N), pathogens, and chemicals. It is essential to combine multiple strategies for the efficient removal of nutrients and pollutants from the water bodies. These approaches include wetlands, retention ponds, and riparian buffer zones

Biochar is a carbon-rich material made by the partial combustion of biomass. It is beneficial in water management because it can remove nutrients and pollutants in aquatic phases. By changing the type of biomass and the burning conditions, as well as applying some pre-treatments, biochar can be created with distinct surface properties. This makes it more effective at removing nutrients and contaminants from water through adsorption, precipitation, and redox reactions. (Wang et al., 2024)

1.2 Objectives

- To evaluate the efficiency of biochar in removing nitrogen (N) and phosphorus (P) from stream water
- To analyze the relationship between water flow and nutrient concentrations in stream water

1.3 Biochar: a sustainable product for nutrient removal

Several technologies exist for controlling nitrogen and phosphorus in water. These technologies include physical methods, chemical precipitation, and biological processes. Most nutrient removal processes have significant challenges. They are difficult to operate and maintain. Many of these methods are expensive. They are also sensitive to environmental conditions. Adsorbents such as biochar offer a better alternative. They are also more economical and more environmentally friendly. This makes adsorbents a better option for removing nitrogen and phosphorus from wastewater (Yin, Zhang, Wang, & Zhao, 2017).

Biochar is recognized as a sustainable material for environmental applications. It has unique physicochemical properties that address multiple environmental challenges. Biochar is produced from waste biomass through pyrolysis. It has a high surface area, rich porosity, and abundant functional groups. These properties enhance its adsorption capacity. This makes biochar effective for removing contaminants from soil and water. Biochar supports climate change mitigation through long-term carbon sequestration. It reduces waste by utilizing biomass. It improves soil quality and agricultural productivity. These combined benefits make biochar a versatile tool. It offers an eco-friendly option for sustainable environmental management. (Wang et al., 2024)

1.4 What is biochar?

Biochar is a carbon-rich material. It is derived from a wide range of biomass or organic waste. The production process uses a thermochemical route. Biochar has gained increasing attention in recent years. This is due to its distinctive properties. It has high carbon content and a large specific surface area. It also has a strong cation exchange capacity. Biochar retains nutrients effectively and has a stable structure (Sakhiya, Anand, & Kaushal, 2020).

1.5 Biochar production

Biochar has been produced for thousands of years. Traditional pyrolysis methods were used for this production. Modern thermochemical methods are now available. These include torrefaction and hydrothermal carbonization (HTC). Gasification is also used. Slow pyrolysis, fast pyrolysis, and flash pyrolysis are other methods. They convert biomass into renewable products. Modern pyrolysis facilities produce more than just biochar. They allow for the separation of volatiles. This separation produces bio-oils and syngas.

Slow pyrolysis is a thermal process in which biochar is heated under anoxic conditions and at relatively low temperatures (typically 300-500 °C) to produce biochar. This process produces by-products, such as bio-oil and syngas, which can be utilized for bioenergy purposes. Fast pyrolysis biochar is produced by rapidly heating biomass (> 500 °C) under anoxic conditions. The process also produces bio-oil and syngas as byproducts. Fast pyrolysis usually focuses on bio-oil production, whereas slow pyrolysis aims to produce more biochar. Gasification, similar to pyrolysis, can lead to biochar production by heating biochar to high temperatures in a controlled environment with limited oxygen supply, producing syngas for energy purposes, with less emphasis on biochar production. (Afshar & Saeed Mofatteh, 2024). Biochar production through thermochemical conversion encompasses several techniques with distinct process parameters and yield distributions, as summarized in Table 1.

Table 1. Process conditions of the Thermochemical conversion methods for biochar production.

Technique	Temperature (°C)	Residence time	Yield of biochar (%)	Yield of bio-oil (%)	Syngas production (%)
Gasification	750–900	10–20 s	10	5	85
Slow pyrolysis	300–700	<2 s	35	30	35
Fast pyrolysis	500–1000	Hour–day	12	75	13
Hydrothermal carbonization	180–300	1–16 h	50–80	5–20	2–5
Torrefaction	290	10–60 min	80	0	20
Flash carbonization	300–600	<30 min	37	–	–

(Yaashikaa, Kumar, Varjani, & Saravanan, 2020)

1.6 Properties of biochar that influence nutrient removal

Biochar's properties play a pivotal role in determining its effectiveness across applications, from agriculture to environmental remediation. These physicochemical properties vary with the raw materials and with the pyrolysis temperature and modification method.

1.6.1 Physical properties of biochar

Surface area: The surface area of biochar is a critical factor in its reactivity and absorption capacity. A larger surface area provides more sites for chemical reactions and nutrient absorption. Biochar is typically produced with higher surface areas using methods such as high-temperature pyrolysis, which increases its potential for soil improvement and environmental functions. (Ingle, Kamble, & Patil, 2024)

Porosity: The porosity of biochar, characterized by its pore size distribution, affects water retention, aeration, and microbial colonization in soils. This porosity improves biochar's ability to retain water, nutrients, and other materials. (Afshar & Mofatteh, 2024)

1.6.2 Chemical properties

Functional groups: Functional groups on the biochar surface, such as hydroxyl, carboxyl, and phenolic groups, influence its chemical reactivity and interactions with nutrients and contaminants. These groups can enhance biochar's cation exchange capacity (CEC). The cation exchange capacity of biochar is a key factor in the ability to retain nutrients. This ability is achieved by the presence of negatively charged functional groups on the biochar surface, which attract and retain positively charged ions in water. Feedstock type and production temperature have a significant influence on CEC. (Venkatesh et al., 2022)

pH: All biochars possess common characteristics of high pH (6.8–10.9). The pH level of biochar varies widely, depending on the feedstock and production conditions. (Fungai N. D. Mukome, Zhang, Lucas, Six, & Parikh, 2013)

1.7 Application of biochar in different types of wastewater treatment

Wastewater can be classified into industrial wastewater, domestic wastewater, agricultural wastewater, and rainwater. All these types of wastewaters must be treated before entering natural water bodies.

The pollutants of the industrial wastewater mainly consist of heavy metals and organic pollutants. Currently, biochar is used primarily in industrial wastewater treatment to adsorb heavy metals and organic dyes. The adsorption process varies depending on the pH of the aqueous phase, exposure time, and dose. (Wang et al., 2024)

Biochar shows strong potential for treating municipal wastewater. It can be used alone or combined with existing technologies like biofilters. Biochar effectively removes both nitrogen and phosphorus from wastewater. This removal capacity depends on several key properties. Biochar has a very high surface area that provides many adsorption sites. It also contains numerous functional groups that bind to nutrients. (Wang et al., 2024)

Biochar and its modified forms are used for stormwater purification. Stormwater runoff often contains harmful levels of metals, organic matter, and biological contaminants. Biofilter and bioretention systems with biochar effectively remove microorganisms from stormwater. Treatment effectiveness depends on the biochar type, contaminant properties, and chemical composition of water. (Wang et al., 2024)

1.8 Biochar in small streams

According to Jiawei et al. (2025), combining biochar with VFS can significantly improve nutrient retention. Research demonstrates that Vegetation filter strips alone reduce nutrient loads in runoff. However, their effectiveness decreases with repeated rainfall events. Total nitrogen (TN) reduction dropped from 38 % to 14 %, while total phosphorus (TP) reduction fell from 33 % to 14 % across the rainfall. The combination of biochar and the srips show much better results. This approach maintains a stable nutrient reduction even during frequent rain. Applying 30 tons/ha of biochar with strips resulted in an average reduction of 54% in total nitrogen (TN), while a higher rate of 90 tons/ha achieved an average reduction of 68% in total phosphorus (TP) over three irrigation cycles.

Barber (2022) evaluated biochar's effectiveness in improving water quality in small streams and ponds across West Virginia, South Georgia, and Prince William County, Virginia. The study focused on mining, municipal, and agricultural areas. Researchers placed biochar in socks, bags, and coir-wrapped tubes at pond and stream inlets to capture nutrients and metals.

In a pond in West Virginia, biochar bags in coir fabric were placed at pond outlets to treat aluminum contamination. Aluminum concentrations initially exceeded the 4.0 mg/L threshold by 9.7 mg/L. After adjusting the pH from below 3 to neutral by using NaOH, aluminum levels decreased to 0.3 mg/L. Another selenium-contaminated pond in the same area used biochar socks stacked at the outlet, along with biochar bags floating in a pond. Initial selenium concentrations exceeded 10 mg/L. After treatment, selenium declined to below 2 mg/L. Algal blooms disappeared within three weeks.

In South Georgia, a five-acre pond collected runoff from over 500 acres of agricultural land. Ten biochar socks were installed and floated in the pond. Within a month, a severe algal bloom was eliminated. Phosphorus levels dropped from 0.8 mg/L to 0.2 mg/L. Total nitrogen decreased from 4 mg/L to 2 mg/L. Biochemical oxygen demand (BOD) fell from 35 mg/L to 4 mg/L.

At a landfill site in Prince William County, Virginia, biochar bags were installed below the outlets of ponds. Phosphorus was reduced from 0.8 mg/L to 0.2 mg/L. BOD decreased from 35 mg/L to 4.0 mg/L. Total nitrogen (TN) dropped from 4 mg/L to 2 mg/L. Additionally, E. coli levels fell from 2,419 CFU/100 ml to 344 CFU/100 ml

1.9 Biochar applications in Finland

Biochar has been investigated in Finland as a potential water protection tool. One study has tested for treating nutrient-rich runoff from peatland forestry areas. Lafdani et al. (2020) conducted a meso-scale laboratory study testing a biochar's adsorption. They used runoff collected from a clear-cut spruce peatland. The study demonstrated significant removal of nitrogen. Total nitrogen decreased by 58% over the eight-week experiment. Both nitrate and ammonium decreased below detection limits within five days of operation. They identified that dissolved organic nitrogen (DON)also adsorbs to biochar. The runoff naturally contained high dissolved organic matter(DOM). The reduction in organic nitrogen suggests that biochar can function effectively in DOM-rich waters. (Elham Kakaei Lafdani, Saarela, Ari Laurén, Jukka Pumpanen, & Marjo Palviainen, 2020)

A recent restoration initiative in the Nuijajoki river basin near Karkkila is testing a limestone-biochar filtration system. The system is designed to address acidic runoff from peatland forestry areas. The Association for Water and Environment of Western Uusimaa (LUVY) developed this approach. It aims to stabilize stream water pH. The pH can drop to harmful levels during heavy rainfall. For example, in spring 2025, the pH in the Kaupinoja stream decreased to 4. Pilot filters were installed in July 2025. They were placed on land owned by the forestry company UPM. This marks the first experiment of this kind in Finland. Early monitoring results show that the system has helped maintain more stable stream pH. The pH has been maintained around 6. Although still in the early testing phase, the pilot demonstrates the potential of combining natural materials such as limestone and biochar for mitigating acidic runoff in small forest streams (Garlo-Melkas, 2025)

1.10 Nutrient removal mechanisms of biochar

Biochar removes nitrogen and phosphorus from water primarily through adsorption. The well-developed pore structure and large surface area provide sufficient space for nutrient adsorption. Total nitrogen in water includes inorganic forms such as ammonium (NH_4^+) and nitrate (NO_3^-), as well as organic nitrogen. Total phosphorus includes inorganic phosphate (PO_4^{3-}) and organic phosphorus compounds.

1.10.1 Influencing factors of nitrogen and phosphorus removal of biochar

Surface area- According to Yin, Zhang, Wang, and Zhao (2017), wood biochar has a higher surface area than rice husk biochar produced under similar conditions. They found that in ammonia solutions, rice husk biochar showed a 60% adsorption rate while wood biochar achieved 73%. These results suggest that higher surface areas improve nitrogen adsorption. However, the surface area is not the only factor affecting nitrogen removal. Other biochar properties also play important roles in removing nitrogen from water. The role of biochar surface area in P removal is similar to that in N removal from water. According to Yin, Zhang, Wang, & Zhao (2017), Peanut shell biochar has a higher surface area (329 m^2/g) than oak biochar (185 m^2/g), bamboo biochar (110 m^2/g), and soybean stover biochar (247 m^2/g) at the same pyrolysis conditions. Thus, the high surface area of peanut shell biochar is one of the contributors to the high phosphate adsorption capacity of 61.3%.

Functional groups- Various functional groups form on the surface of biochar during biomass pyrolysis. Carbonyl, carboxyl, hydroxyl, and phenolic hydroxyl groups are key functional groups. The ion exchange occurs between functional groups and $NH^+{}_4/NO_3^-$ ions. Therefore, functional groups play a critical role in N adsorption. Acidic functional groups in biochar gain a negative charge when they ionize in water. Positively charged ammonium ions are attracted to these negatively charged sites. (Yin, Zhang, Wang, & Zhao, 2017).

pH of water - The pH of the water phase has a significant impact on nitrogen adsorption. In the pH range of 4-8, ammonium is efficiently removed from water by biochar through ion exchange. At lower pH values (below 4), hydrogen ions compete with ammonium for active sites on the biochar surface. This competition reduces the adsorption capacity (Yin, Zhang, Wang, & Zhao, 2017). At lower pH levels, phosphate is more easily captured by biochar. However, at higher pH levels, the phosphate removal efficiency decreases because other negatively charged particles (OH-) in the water compete with phosphate for adsorption sites on the biochar surface. (Park et al. 2015).

Coexisting ions- The Zn^{2+}, Al^{3+}, HCO_3^-, CO_3^{2-}, and PO_4^{3-} ions in water can reduce the NH_4^+ adsorption. They compete for active sites. Presence of Cl^-, NO_3^-, or SO_4^{2-} ions in water has no significant effect on NH_4^+ adsorption by biochar. (Yin, Zhang, Wang, & Zhao, 2017)

Metallic oxides- Certain biochar types show enhanced phosphate removal. This is due to nano-sized magnesium oxide particles on the surface. The magnesium oxide surface is usually positively charged in water. Phosphate species are negatively charged. They are electrostatically attracted to the positively charged magnesium oxide surface. Additionally, some magnesium oxide dissolves in the solution. Chemical reactions occur between dissolved magnesium and phosphate. These forms precipitate as magnesium phosphate compounds. (Yin, Zhang, Wang, & Zhao, 2017).

Surface charge- The surfaces of carbon-based materials are often negatively charged. Hence, it is difficult to absorb ions with a negative charge in water. In several cases, the surface charge of biochar changes after activation, thereby affecting phosphate adsorption capacity. The activation of biochar with ZnCl2 changes its surface charge from negative to positive, which is an essential reason for the high adsorption capacity (93.9%) of negatively charged phosphate (Park et al. 2015).

Hydrological factors - According to Wang et al. (2024), Several hydrological factors affect the adsorption mechanism of biochar in water. These factors determine the interaction between water and biochar. Contact time plays a critical role in pollutant removal. Longer contact time increases adsorption on the biochar surface.

The pH of the water impacts nutrient adsorption. pH changes the surface charge of biochar. It also affects the chemical forms of dissolved nutrients and minerals. Nutrient concentration and temperature also influence biochar performance. They affect the movement and diffusion of contaminants within the pores of biochar.

Repeated use of biochar filters causes gradual changes in their physical structure. The pore size and surface area decrease over time. It leads to slower water penetration through the material. Consequently, the overall adsorption efficiency declines with continued use.

Studies demonstrated that biochar performs well in surface water treatment applications. However, its pollutant removal performance is not constant. Key factors, including runoff volume, flow velocity, and water chemistry, significantly influence treatment efficiency.

1.11 Biochar modifications to improve nutrient emoval capacity

Biochar has been widely used to remove various contaminants from water. However, its application faces certain limitations. Unmodified biochar exhibits relatively poor removal capacity. The aim of biochar improvement is to enhance its ability to remove contaminants. Biochar modification includes several key strategies. One focuses on increasing the surface area and porosity. Another strategy aims to improve surface properties. The third method consists of inserting additional materials into the biochar matrix. This creates beneficial combined materials with enhanced performance. (Wang, Guo, Hu, & Zhang, 2020) Fig.1 summarizes the major biochar modification strategies based on their primary functional emphasis, along with representative techniques and reagents reported in the literature.

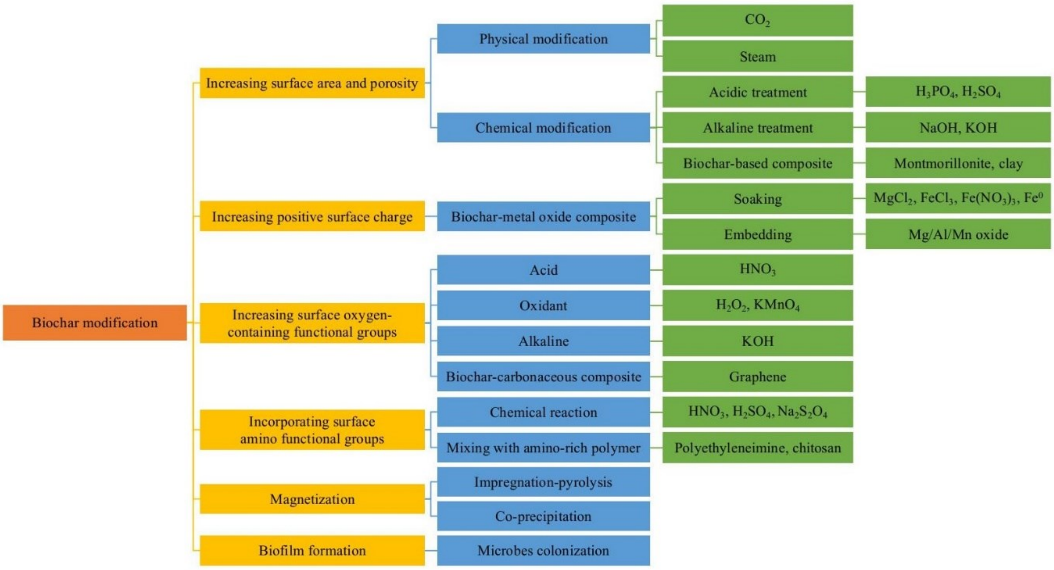

Fig. 1: Modification methods of biochar according to different emphases. (Wang, Guo, Hu, & Zhang, 2020)

Increasing surface area and porosity

Physical modification uses CO2 or steam at temperatures exceeding 700 °C. This treatment increases surface area and porosity (Wang, Guo, Hu, & Zhang, 2020). Steam activation removes incomplete combustion residues and enhances porosity. These changes increase available adsorption sites.

Zhang et al. (2004) studied CO2 treatment effects on biochars from corn stover, corn hulls, and oak wood. All biochar types showed improved adsorption capacity with longer treatment times.

Acidic or alkaline treatments enhance surface area. Pre-treated wood sawdust with diluted H3PO4, which increased both surface area and pore volume. Pyrolyzing biochar-KOH mixtures at 350-550 °C reopens blocked pores and expands smaller pores. This increases surface area. Similarly, NaOH modification improves adsorption capacity by enhancing porosity and surface area (Wang, Guo, Hu, & Zhang, 2020)

Increasing positive surface charge

Acidic or alkaline treatments enhance surface area. Pre-treated wood sawdust with diluted H3PO4, which increased both surface area and pore volume. Pyrolyzing biochar-KOH mixtures at 350-550 °C reopen blocked pores and expand smaller pores. This increases the surface area. Similarly, NaOH modification improves adsorption capacity by enhancing porosity and surface area (Wang, Guo, Hu, & Zhang, 2020)

Increase surface functional groups (oxygen-containing)

Biochar surfaces contain oxygen functional groups, including carboxyl, hydroxyl, and phenolic groups. These groups bind chemically with contaminants. Acidic treatments (HNO_3, H_2SO_4) enhance these functional groups and improve cation adsorption. Alternative oxidants ($KMnO_4$, H_2O_2) and alkaline treatments (KOH) produce similar effects. (Wang, Guo, Hu, & Zhang, 2020).

2 Methodology

2.1 Study area

Fig 2- Map of the Västankvarn Gård in Finland

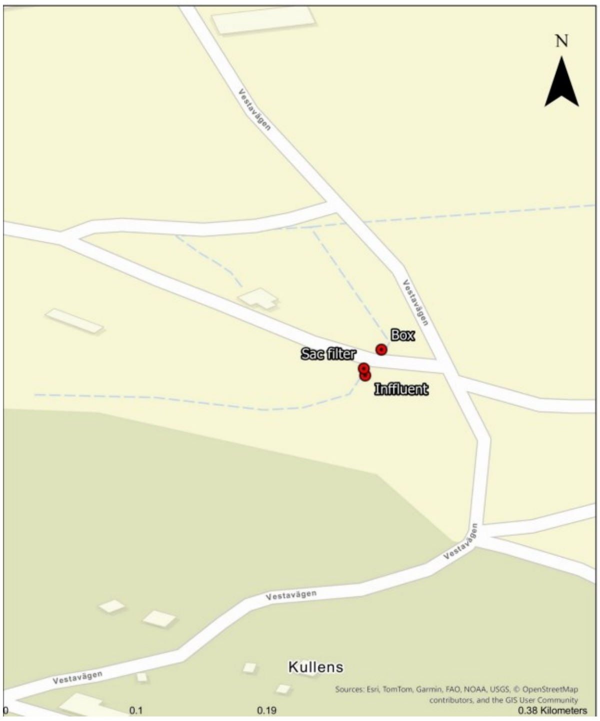

Fig 3- The map of three sampling points in the small stream

The study was conducted in a small stream at Västankvarn Gård farm (60.07482° N, 23.88019° E) in Ingå, Finland (Fig.2) . The stream originates from the surrounding forest area, flows behind two cow barns, and discharges into Ingå River. The selected stream area has an average width of 1.78 m and depth of 0.33 m with slightly sloped terrain. Stream flow varies seasonally, with minimal flow during mid-summer (July), reflecting typical dry-season conditions in southern Finland. The soil type is primarily clay, and there are low grasses with no tree vegetation cover along the streambanks.

The surrounding landscape is dominated by agricultural land, with residential houses within 300 m. This site was selected because the stream flows directly behind the cow barns, where nutrient concentrations likely are high. The site, therefore, provides a suitable location for evaluating biochar filter nutrient removal efficiency under real field conditions in an agriculturally influenced environment.

2.2 Design of the biochar filters

The biochar used in this study was produced within the farm area where the biochar filter was implemented. The feedstock consisted of wood chips collected from the surrounding farm area. The biochar was prepared by slow pyrolysis process conducted under anaerobic conditions. The inlet temperature is approximately 100 °C, and the outlet temperature reaches about 800 °C. The biochar had an ash content of approximately 2%. The particles were irregularly shaped and between 20 mm and 50 mm in diameter. The biochar was used as is, without sieving, pre-washing, or chemical pre-treatment.

Sac biochar filter

The sac biochar filter was constructed using 40L coir bags, each filled with 30L of loosely packed biochar . It ensures even water flow through the filter media. The bags were securely sealed with coir string to prevent leaks. Eight biochar-filled bags were placed across the stream. This procedure formed a dam-like structure, 1.78 m in width and 0.31 m in height. This setup aimed to maximize contact time between the stream water and the biochar to improve its ability to remove nutrients.

Fig. 4: The sac Biochar filter implemented across the stream

Fig. 4 shows how the biochar filters were positioned across the small stream to act as a small, dam-like barrier.

Box biochar filter

The box biochar filter was constructed using a metal-framed Intermediate Bulk Container tank with dimensions of 1.2 m × 1.0 m × 0.58 m. The tank was cut to half its original height (0.58 m) and thoroughly cleaned. Three holes were cut on one of the shorter sides near the bottom of the tank to install three corrugated drainage pipes. Each pipe had a diameter of 0.05–0.075 m and a length equal to the inner length of the tank (1.2 m). These pipes were positioned parallel to each other and served as outlet pipes. A layer of wood chips, approximately 0.10–0.15 m thick and with a particle size of 0.02–0.05 m, was placed above the drainage pipes. This layer served as a support medium to prevent clogging of the outlet system. Above the wood chip layer, approximately 300 L of biochar was added to form the main filtration bed, resulting in a biochar layer depth of about 0.30–0.35 m. At the inlet of the tank, a 0.40 m-diameter metal lid was placed to serve as a diffuser. This is to promote even distribution of influent water and minimize localized flow or channeling. The completed box biochar filter was positioned approximately 10 m downstream of the sac biochar filter. This arrangement allowed the effluent from the sac biochar filter to flow into the box biochar filter for further treatment, improving overall water quality through a two-stage filtration process.

Fig 5: box Biochar Biochar filter

Fig. 5 illustrates the box biochar filter fitted with a metal-lid diffuser. The water inlet can also be clearly seen in the figure.

2.3 Water Sampling

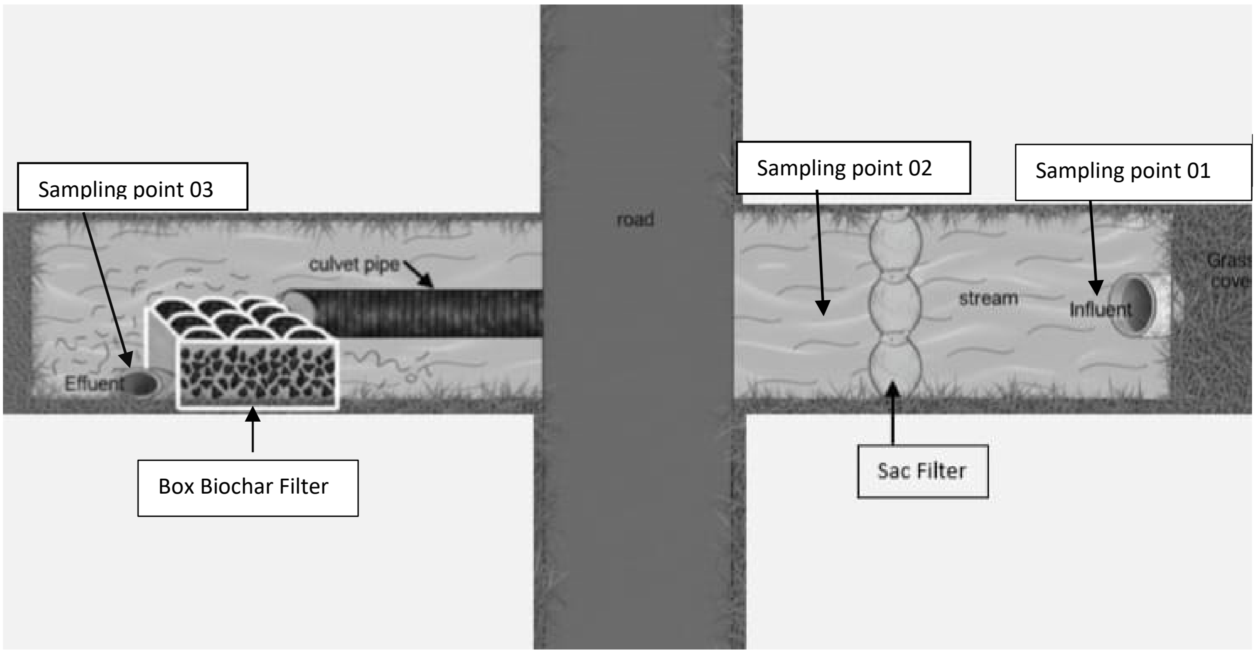

Fig 6. The schematic diagram of the three sampling points.

Schematic of the experimental setup showing influent flow through a sac filter and box biochar filter beneath a road culvert, with sampling points -01. Influent before filters 02- after sac biochar filter, and 03- effluent after two filters (Fig.6).

Water samples were collected from the three sampling points once every two weeks, starting on July 7, 2025, for a total of 8 sampling times. At each sampling point, I collected 2 L of water in plastic bottles and kept the samples in a cooler box. The samples were then brought to the LUVY laboratory, a certified analytical laboratory, for further analysis. The measured parameters included total nitrogen (TN) and total phosphorus (TP), which were the primary objectives, along with pH and turbidity, as supporting variables. The laboratory has followed standardized analytical procedures based on ISO and EN methods. Total nitrogen SFS-EN ISO 11905-1:1998,SFS-EN ISO 13395:1997,total phosphorus, P SFS-EN ISO 6878:2004 , Turbidity SFS-EN ISO 7027-1:2016 and pH SFS 3021:1979

At the beginning of the study, I planned to collect 10 samples; however, I was able to collect only 8. After about four months, both biochar filters became inactive due to heavy sediment clogging and the decay of the sac bags.

2.4 Data analysis

The results were presented using tables and graphs. ANOVA was used to determine whether there were significant differences between averages in total nitrogen and total phosphorus between the three sampling points, using Microsoft Excel.

2.5 Water flow rate

The stream flow rate was categorized on a 1–5 scale during each sampling event, based on visual observation of water movement. The categories were defined as follows. 1 – very low flow with slow water movement 2 – slightly increased but still gentle flow 3 – moderate flow conditions 4 – fast-moving, high flow 5 – very high flow with clearly rapid water movement.

This qualitative scale was applied to examine the relationship between stream flow rate and influent nitrogen concentrations.

3 Results

High concentrations of total nitrogen (TN) and total phosphorus (TP) were identified at all three sampling points: influent, after the SAC biochar filter, and final effluent. The results are presented using line charts to illustrate temporal trends and boxplots to summarize the distribution, median values, and variability of nutrient concentrations across the treatment stages.

3.1 Total nitrogen and total phosphorus

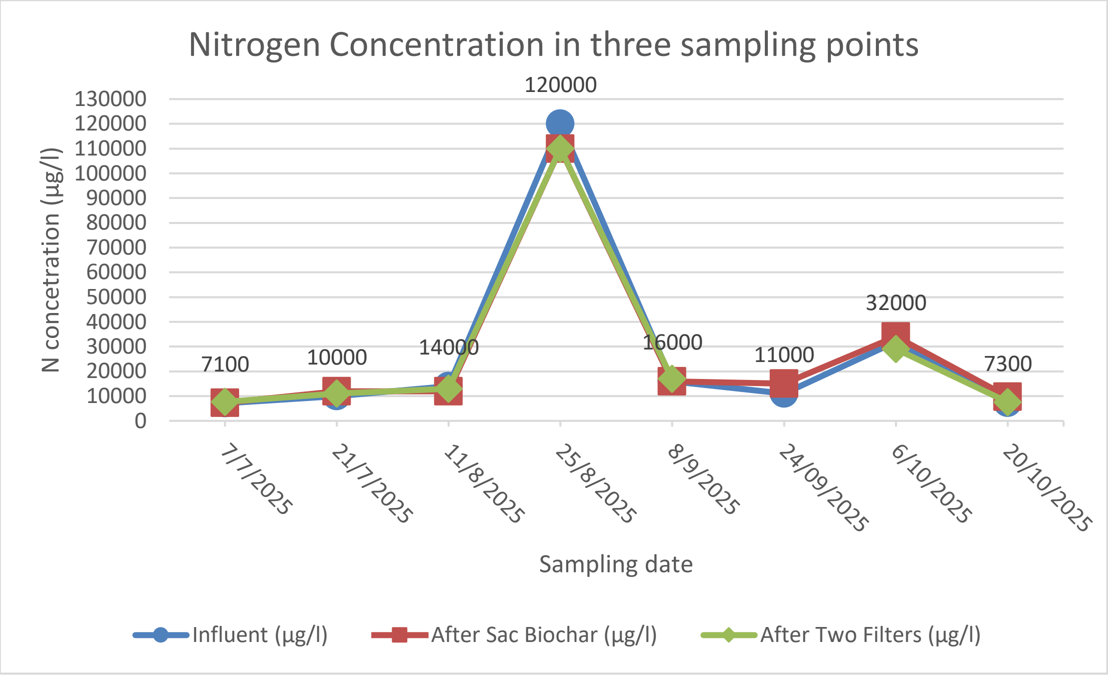

Fig.7. The figure above shows the total nitrogen concentration at three sampling points over time.

Influent total nitrogen levels varied from 7,100 µg/L (07/07/2025) to 120,000 µg/L (25/08/2025). These values are very high, indicating poor water quality. Effluent TN concentrations remained similar to or exceeded influent values (Fig 7). On 24 September 2025, the box filter became clogged with mud. Water overflowed instead of passing through the filter media. Therefore, no effluent data were recorded on that date.

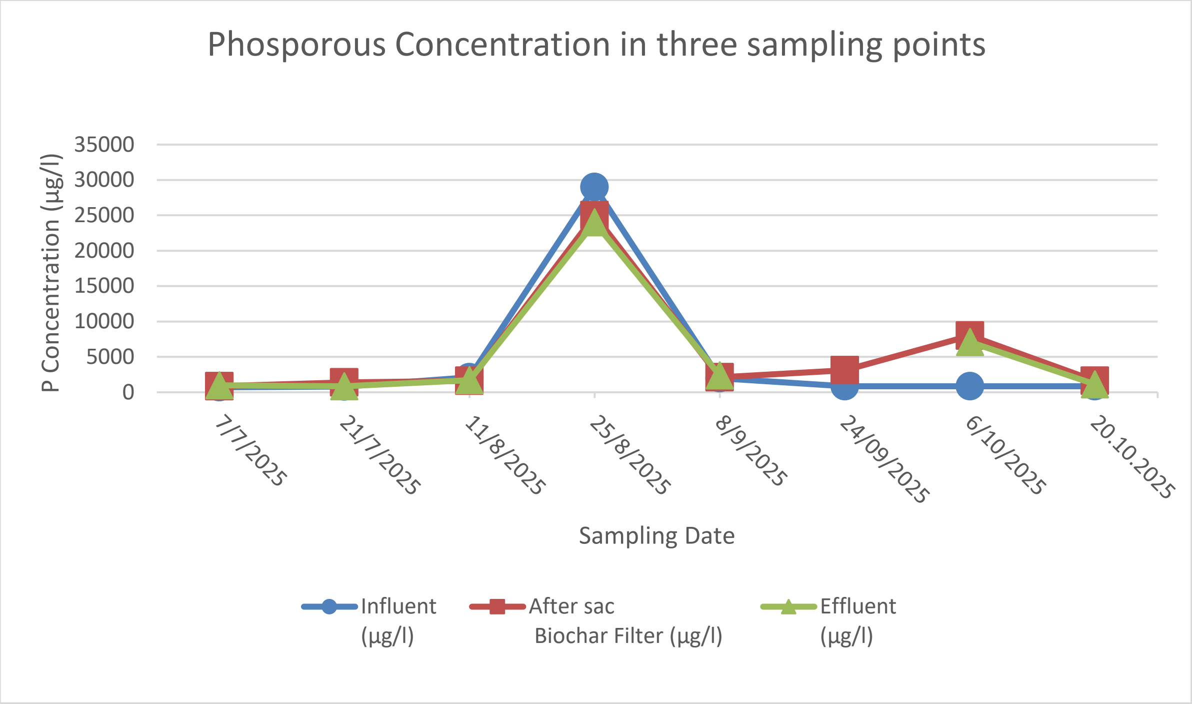

Fig. 08. Total phosphorus concentration at three sampling points over time

Fig.8 illustrates Total Phosphorus (TP) concentrations at three sampling points during the study period. TP concentrations changed significantly throughout the sampling period. The highest influent value was 29,000 µg/L on 25/08/2025. Most other sampling dates recorded influent values between 710 and 2,100 µg/L. Effluent concentrations stayed similar to or higher than influent values. On 24/09/2025, no effluent data were recorded because the filter became clogged.

3.2 Statistical analysis of influent and samples from two filter stages

A one-way ANOVA was conducted to compare the mean total Nitrogen concentrations across the three treatment stages: Influent, After SAC biochar filter, and After two filters (Effluent). Mean TP concentrations decreased slightly from influent (29486 µg/L) to the SAC biochar filter (28728 µg/L) and the effluent (27900 µg/L). The analysis reveals no statistically significant difference among the three groups, F(2, 18) = 0.003, p = 0.997. This indicates that the treatment stages did not produce a meaningful change in the measured variable.

Next, a one-way ANOVA was conducted to compare Total Phosphorus (TP) concentrations across the Influent, After SAC Biochar Filter, and Effluent. Mean TP concentrations decreased slightly from influent (6164 µg/L) to the SAC biochar filter (5794 µg/L) and the effluent (5447 µg/L). However, the ANOVA results showed no statistically significant difference, F(2,18) = 0.0105, p = 0.9895, as the p-value was > 0.05. This indicates that TP concentrations did not differ significantly among the three treatment stages. The treatment process, including both the SAC biochar filter and final box biochar filtration step, did not produce a statistically significant reduction in TP concentrations during the sampling period.

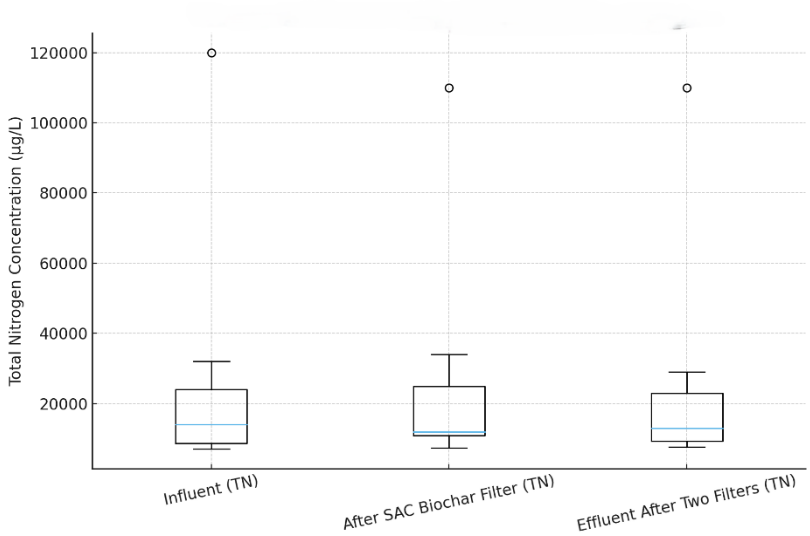

Fig. 9- Total nitrogen Concentrations in Influent, SAC Biochar Filter, and Effluent with average values; blue lines indicate median values

The boxplot shows that Total Nitrogen concentrations vary widely at each treatment stage (Fig. 9) . All sampling points contain high outliers ranging from 110,000–120,000 µg/L. The median TN concentration is similar across the influent, SAC biochar filter, and final effluent. This indicates minimal nitrogen reduction through the filtration system.

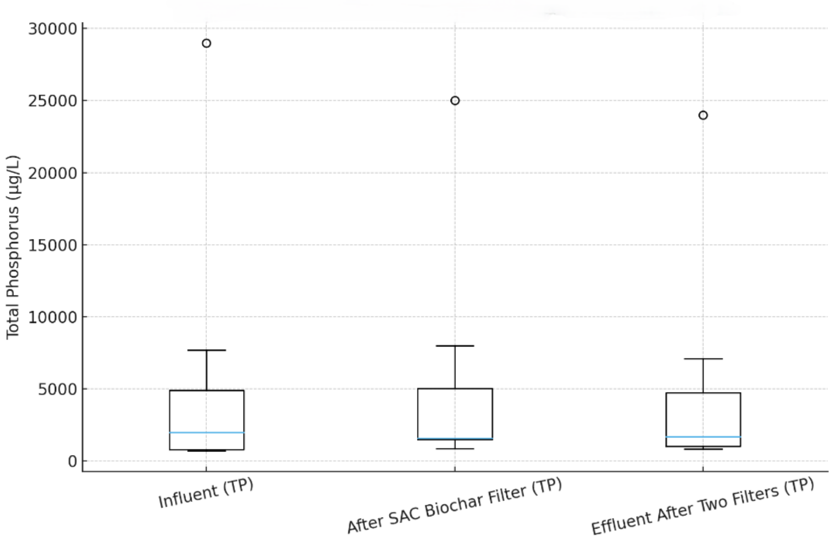

Fig. 10 – Total Phosphorus Concentrations in Influent, SAC Biochar Filter, and Effluent with average values; blue lines indicate median values.

The boxplot (Figure 10) shows Total Phosphorus concentrations across the three treatment stages. All three stages show similar median values. This indicates that TP concentrations stayed relatively consistent throughout treatment. Each stage has one high deviation between 24,000 and 29,000 µg/L from occasional peaks. The median TP values are slightly lower after treatment, but the differences are very small.

3.3 pH and turbidity variation

pH and turbidity were measured at the three sampling points as supporting variables for the main study objective.

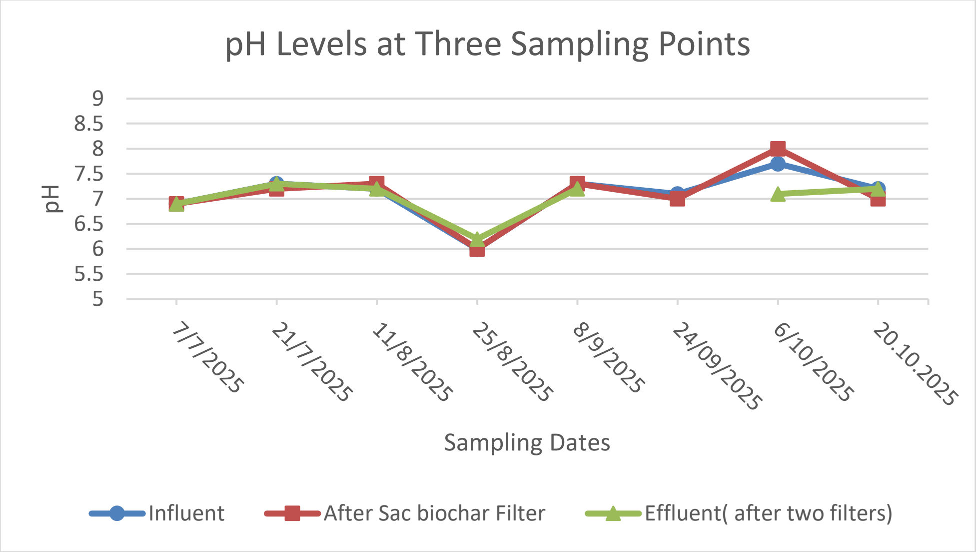

Fig. 11- The pH values measured at the three sampling points throughout the monitoring period.

Fig. 11 illustrates the pH levels throughout the monitoring period. pH remained relatively stable at all three sampling points. The lowest pH (6.0) was observed on August 25. The highest pH (8.0) occurred on October 6. pH values of the influent, sac filter, and effluent were nearly identical. They typically varied by less than 0.2–0.3 units. This indicates that the biochar filtration system had minimal impact on stream water pH.

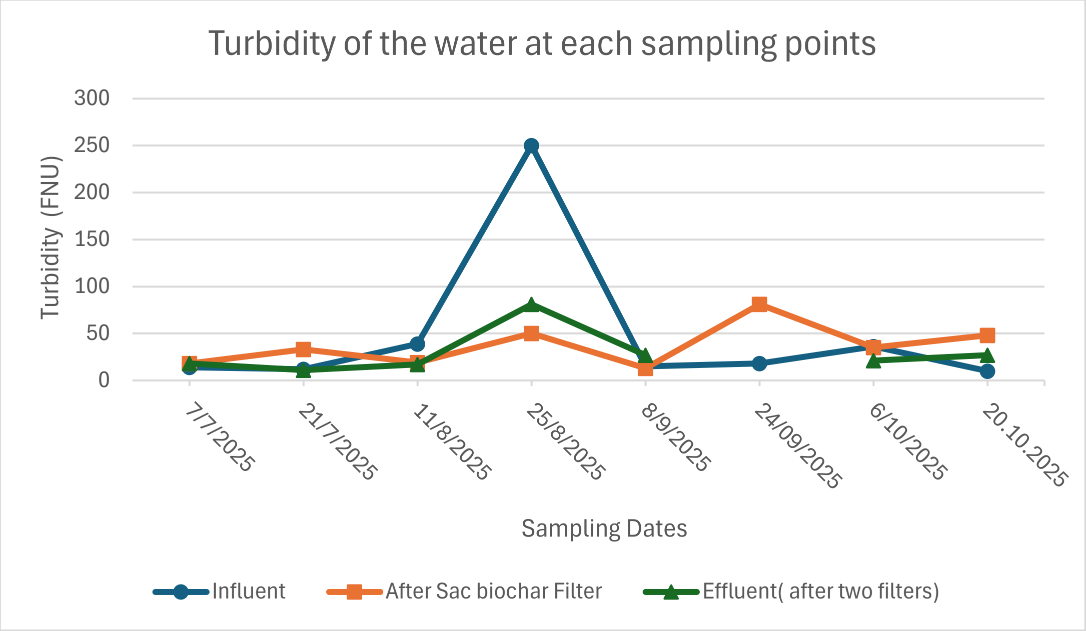

Figure 12. The turbidity values were measured at the three sampling points throughout the monitoring period.

The graph shows the variation in turbidity over the sampling period. The highest value was observed in the influent on August 25 (250 FNU). Turbidity sometimes increased after the sac biochar filter. However, the final effluent values were generally close to the influent on most sampling dates. Only minor reductions or increases were observed from influent to effluent. This indicates that the two-stage biochar system did not provide consistent turbidity removal.

3.4 Stream flow rate and nutrient concentration

The stream flow rate was categorized on a scale from 1 to 5 during each sampling event. This scale was based on visual observation of water movement. 1- very low flow with slow water movement. 2 - slightly increased but still gentle flow. 3 - moderate flow conditions. 4- fast-moving high flow. 5 - very high flow with clearly rapid water movement. This scale was used to explore the relationship between stream flow rate and influent nitrogen concentrations.

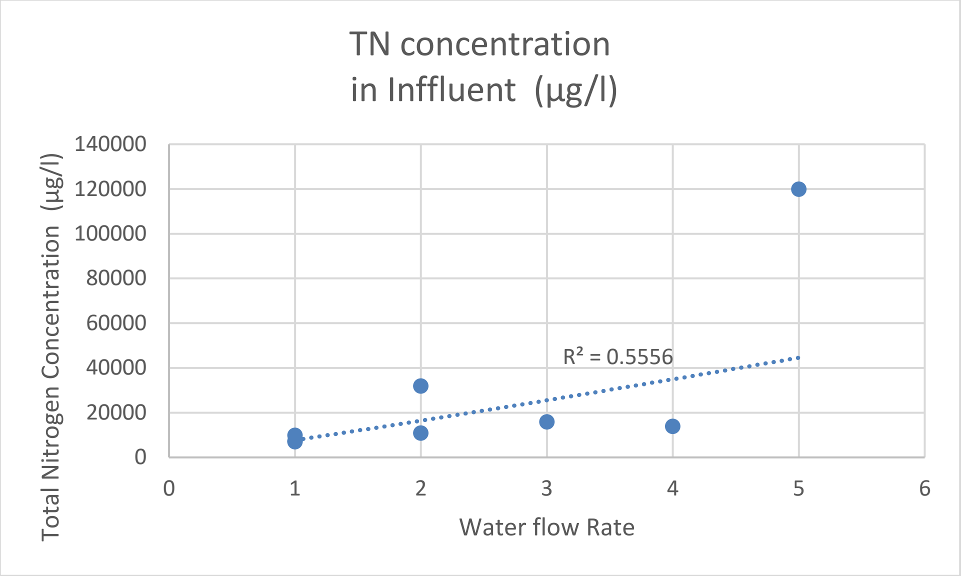

Fig. 13- correlation between flow rate and total nitrogen concentration in the Influent in 8 samples.

The graph shows that TN concentration increases with the rise in water flow rate (Fig. 13). The R² value of 0.56 indicates a moderate relationship between the two variables. This means that flow rate accounts for roughly half of the variation in TN concentration.

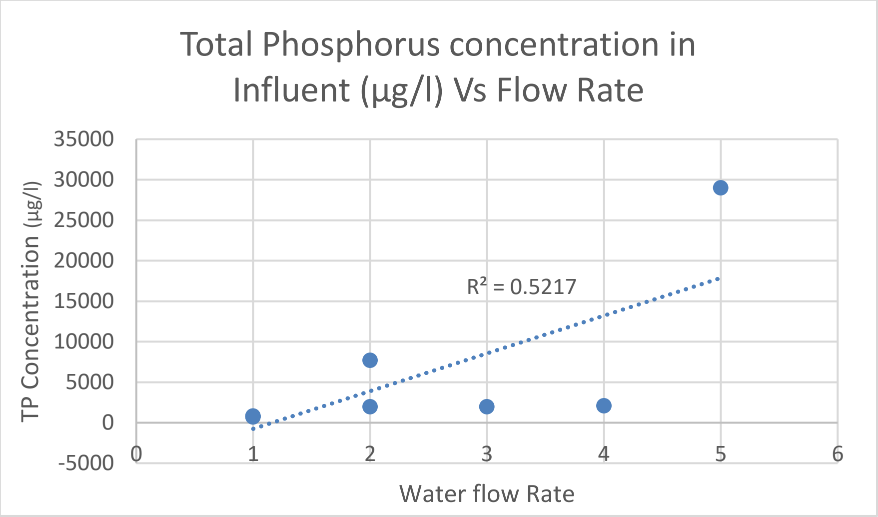

Fig.14 - The figure shows the correlation between Flow Rate and Total phosphorus concentration in the Influent in 8 samples .

The scatter plot illustrates the correlation between flow rate and total phosphorus (TP) concentration in streamflow (Figure 14). The trendline shows that TP concentration increases with flow rate. The R^2 value is 0.52, indicating a moderate correlation. This means 52% of the TP variation is explained by flow rate. TP concentration is higher at higher flow rates, especially at flow rate 5.

4 Discussion

This study evaluated a two-stage biochar filtration system for removing Total Nitrogen (TN) and Total Phosphorus (TP) from an agricultural stream. The results showed that the system did not achieve significant reductions in nutrient levels. Statistical analysis confirmed no significant difference in nutrient concentrations between influent, sac biochar filter effluent, and final effluent or after box biochar filter .

The pH values ranged from 6.0 to 8.0 at all three sampling points. This range is slightly wider than the typical Finnish freshwater pH (6.5–6.8). (Acidity | Vesi.fi, 2020) The influent and effluent followed the same pattern. This shows that the pH changes were due to natural conditions, not due to the biochar filters. The low pH in late August was likely due to rainfall. Rainwater is slightly acidic and can lower stream pH. Runoff also brings organic acids from soil, which reduces pH further. The higher pH in early October is typical during low-flow periods. Overall, the biochar filters did not significantly change pH. However according to Yin et al. (2017), ammonium adsorption by biochar is most effective within a pH range of 4–8. Similarly, phosphate removal is efficient under lower pH conditions,because removal efficiency declines at higher pH because hydroxide ions (OH^-) compete with phosphate for adsorption sites on the biochar surface (Park et al., 2015). Therefore, the pH of the stream water was not optimal for phosphate adsorption. This suggests that pH conditions were not supportive of strong nutrient removal.

Turbidity varied a lot during the study, with the highest value (250 FNU) measured in the influent on August 25. In some cases, turbidity even increased after the sac biochar filter, and the final effluent was usually similar to the influent. This shows that the two-stage biochar system did not consistently reduce turbidity. After the clogging event, turbidity increased even more because the box filter started releasing the sediment that had built up inside it.

The poor performance observed in this study compares with successful biochar applications reported in similar field studies. Jiawei et al. (2025) found that combining biochar with vegetation filter strips in riparian zones reduced TN by up to 59.9% and TP by up to 75.7% under continuous rainfall conditions. However, their study applied biochar to soil at rates of 30-90 tons/ha. It has improved nutrient retention.

Barber et al. (2022) reported successful biochar applications in small streams and ponds. The study shows the phosphorus reduction from 0.8 mg/L to 0.2 mg/L (75% reduction) and total nitrogen from 4 mg/L to 2 mg/L (50% reduction) within one month. Barber's and his co-authors' study used ponds with much lower flow rates and longer retention times compared to the flowing stream in this study. The initial nutrient concentrations in their work were considerably lower than those observed in this study, where TN ranged from 7,100–120,000 µg/L and TP from 710–29,000 µg/L.

Several limiting factors can be identified that influenced the low effectiveness of the biochar filter system in my study. One limiting factor relates to the properties of the biochar used. The biochar was produced through slow pyrolysis at approximately 800°C using wood chips from the farm area. The biochar received no pre-treatment, washing, or activation before deployment. Literature clearly shows that biochar modification significantly improves nutrient removal capacity. According to Wang, Guo, Hu, and Zhang (2020), modification methods target three main improvements. Increasing surface area and porosity, enhancing positive surface charge, and increasing surface functional groups. The lack of such modifications in this study limited the nutrient removal efficiency. The particle size of 20-50 mm may also negatively affect the nutrient removal. Larger particles prevent washout with stream flow. However, they reduce the surface area-to-volume ratio available for water contact. Smaller particles or crushed biochar would provide more adsorption sites per unit volume. This could potentially improve treatment efficiency for both nitrogen and phosphorus removal.

The second limiting factor relates to the design of the filtration system. Both filters had design limitations that reduced their effectiveness. The sac biochar filter consisted of eight 40L coir bags filled with 30L of biochar. The bags were arranged across the stream to create a dam-like structure. However, some water passed between the bags rather than flowing through the biochar material, since water flows downwards and follows the easiest path. In addition, the coir sack material was not durable enough. The majority of the bags began to decay after about four months. This damaged the structure and reduced treatment performance. Box biochar filter had only one inlet, which created an uneven flow through the filter. The metal lid at the inlet worked as a diffuser and it was not sufficient to create an even water distribution throughout the whole box. Therefore, this causes water channeled through certain areas which reduced the amount of biochar is actually treating the water. On the other hand, water moved so quickly through the filter system. Therefore, the system suffered from insufficient water retention time. Wang et al. (2024) emphasized that adequate contact time is essential for effective nutrient removal.

Third, biochar filters became inactive due to sediment accumulation and clogging. The filter system lacks pre-sediment removal. Agricultural streams carry a high amount of suspended solids, especially during rainfall. Without settling basins or sediment traps upstream, these sediments entered directly into the biochar filters. This caused clogging and reduced the efficiency of adsorption. After approximately three months, the sediment layer in the box filter became so dense that most of the water did not pass through the biochar. The clogging event that occurred on 24 September 2025 shows this problem clearly. Once the box filter filled with mud, water could no longer flow through the biochar. Instead, water overflowed the box without being treated.

Another significant limiting factor is the extreme nutrient pollution in the stream. Peak concentrations reached 120,000 µg/L TN and 29,000 µg/L TP. These values represent pollution loads much higher than typical agricultural runoff. The average concentration remained exceptionally high throughout the study. Mean values were 27,300 µg/L TN and 5,644 µg/L TP. These high concentrations indicate that the system continuously experienced nutrient loads well beyond the capacity of passive biochar filters.

Even well-designed biochar filtration systems have limited treatment capacities. When nutrient loads exceed this capacity, the treatment efficiency collapses. The extremely high nutrient concentrations in this study suggest that the system was overloaded from the beginning. Ahmadvand et al. (2018) provide evidence for this mechanism. They found that the adsorption efficiency decreases at high concentrations due to saturation of adsorption sites. Their experimental data showed that increasing nitrate concentration from 10 to 320 ppm caused the removal efficiency to drop from 23–37% to 6–11%. These findings support the interpretation of poor performance conditions in this study. Adsorption sites on the biochar were likely saturated with high nutrient concentration within a shorter period of time.

One of the most remarkable findings of this study is the exceptionally high nutrient concentrations in the stream. These concentrations indicate a severe decline in water quality. Throughout the monitoring period, total nitrogen (TN) levels ranged from 7,100 µg/L to 120,000 µg/L. The mean concentration exceeded 27,000 µg/L. Total phosphorus (TP) concentrations were similarly elevated. They ranged from 710 µg/L to 29,000 µg/L. They highlight the urgent need to address the sources of nitrogen and phosphorus inputs.

These nutrient levels reflect the intensive agricultural activities in the catchment area. The stream flows directly behind two cow barns at Västankvarn Gård farm. Agricultural runoff, forest drainage, and potential effluent from the cow barns are the main possible contributors to the high nutrient loads. The clay-rich soils in the area may also enhance nutrient removal from soil during rainfall events.

The stream discharges into the Ingå River, which subsequently flows into the Baltic Sea. This emphasises that every microgram of nitrogen and phosphorus leaving this small agricultural stream contributes to nutrient loading in the Baltic Sea. Therefore, developing effective treatment strategies for small agricultural streams is not merely a local water quality concern but a critical component of broader efforts to protect the Baltic Sea ecosystem. Therefore, proper treatments for small agricultural streams are crucial for protecting the Baltic Sea.

The study identified a moderate positive correlation between stream flow rate and both nitrogen and phosphorus concentrations in the influent. These correlations indicate that approximately half of the variation in nutrient concentrations can be explained by flow rate changes. Higher flow rates corresponded with higher nutrient concentrations. For instance, on August 25, 2025, when the flow rate reached level 5 and nutrient concentrations peaked. However, the moderate R^2 values indicate that flow rate alone does not fully explain nutrient variability. Other factors also influenced nutrient concentrations in the stream, the stream originates from a forest area, but then passes behind two cow barns and continues through farmland. This creates multiple potential sources of nutrient input. Barnyard runoff most likely adds additional contamination. Diffuse agricultural runoff from surrounding farmland also introduces nutrients. These inputs can occur even during low-flow conditions. This explains why both high and low nutrient concentrations were observed at similar flow rates.

Nutrient levels showed dramatic changes within two-week intervals. TN decreased from 120,000 µg/L on August 25 to 16,000 µg/L on September 8, an 87% reduction. TP dropped from 29,000 µg/L to 2,000 µg/L during the same period, a 93% decrease. However, high nutrient concentrations also occurred at low flow rates. On October 6, 2025, TN reached 32,000 µg/L and TP reached 7,700 µg/L at flow rate 2. On the other hand, the sampling frequency of once every two weeks may have missed important changes in water quality. More frequent sampling would provide a better understanding of pollution patterns and system behaviour.

The monitoring period of about 3.5 months (July to October) captured late summer and autumn conditions but did not include winter or spring. Seasonal changes in temperature, rainfall, vegetation, and farm practices all affect nutrient transport. The study period was also shorter than planned. Ten samples were originally planned, but only eight were collected because both biochar filters became inactive in roughly 3.5 months. However, this operational failure still provides useful information about system limitations under real field conditions.

The results show a clear need for source control measures to reduce nutrient inputs before the water reaches the stream. The very high nutrient concentrations suggest that cow barn effluent is likely entering the stream with little or no pre-treatment. Improved manure management would lower nutrient loads and improve the performance of downstream treatment systems. The most important step is to implement a proper ban-yard discharge treatment plant before banyard effluent is discharged to the stream.

Useful source control measures include treating barn wastewater before discharge. Maintaining suitable vegetative cover along the stream is also an important measure. Another suggestion is to place vegetative buffer strips with mixed biochar between the barns and the stream. It will provide further support for natural filtration. Jiawei et al. (2025) showed that combining biochar with vegetated filter strips increases nutrient retention more than using biochar alone.

The findings of this study highlight several important recommendations for improving biochar-based treatment systems and guiding future research. Key improvements include a thorough baseline study, pre-treatment for sediment removal, increase nutrient contact time with biochar, multiple treatment stages and integrated treatment approach.

Before implementing any biochar filtration system, it is essential to analyze the nutrient composition of the stream water. A thorough baseline assessment helps to understand the concentrations and forms of nitrogen and phosphorus in water. Then it helps to select suitable biochar modifications or pre-treatments. Further guides the design of the filtration unit.

The system should include settling basins or coarse filtration upstream of the biochar filters to remove suspended solids . A settling basin is especially useful because it not only traps sediments but also helps slow the flow rate, creating more stable conditions for the biochar filters to operate effectively. A series of two or three settling basins arranged in sequence would allow more particles to settle out before water reaches the biochar filters. These basins could be simple excavated areas with sufficient volume to reduce flow velocity and promote sedimentation. Regular maintenance to remove accumulated sediment would be essential.

Following sediment removal, multiple biochar filter stages should be installed along the stream to provide better removal than all filtration in one location. Installing three to four separate biochar filter units at intervals of 50-100 meters would provide extended contact time and multiple opportunities for nutrient removal.

In addition, incorporating multiple sand layers between the biochar layers in the box filter could further slow water flow through the filter. This would enhance retention time. A multilayer structure would help ensure more uniform water movement. However, it is important to use clean sand with low nutrient content. This avoids introducing additional contaminants into the system.

High nutrient concentrations observed in this study emphasized that a combined approach would be more effective. Therefore, biochar filtration should be integrated with other nutrient control measures. Jiawei et al. (2025) demonstrated that pairing biochar with vegetated filter strips substantially enhances nutrient retention. Establishing vegetative buffers along the stream corridor would provide additional natural filtration. It would also stabilize stream banks and support habitat conditions.

Constructed wetlands could provide biological nutrient removal through plant uptake and microbial processes. This would enhance the physical and chemical removal mechanisms of biochar. The wetland would also provide a flow velocity decline and sediment settling. This would protect downstream biochar filters from clogging. Integrating a constructed wetland into the treatment system would substantially improve nutrient removal in this stream. It would overcome most of the limitations observed in the current biochar filters.

A wetland would greatly increase water retention time for biochar adsorption. Slower and more stable flow conditions would reduce the nutrient pulses associated with high-flow events. This would prevent the bypassing and clogging issues seen in the existing filters. Within the wetland, biochar bags could be placed among vegetation. This would combine multiple treatment mechanisms. These include adsorption, plant uptake, microbial transformation, and sedimentation. Wetland plants would further support nutrient removal and system stability. Overall, integrated nutrient removal approaches with biochar are expected to provide more reliable and efficient pollutant reduction than passive biochar filters alone.

5 Conclusions

In this study, the two-stage biochar filter system did not show efficient nutrient removal in the small stream. Even though the work provides an essential foundation for future biochar applications in streams influenced by agriculture. The filters in this study faced several challenges, including extremely high nutrient loads, sediment clogging, and insufficient water retention time. A more detailed baseline assessment could help address these issues and guide the selection of more suitable biochar materials and filter designs.

The study also highlights the complexity of agricultural streams, particularly in relation to nutrient dynamics and management. Effective nutrient-reduction measures are crucial because these small streams transport nutrient loads toward sensitive aquatic ecosystems such as the Baltic Sea. This work shows that biochar alone is unlikely to achieve meaningful nutrient reduction under such conditions and that integrated approaches are needed.

Furthermore, the findings of this study emphasize the importance of continuous water-quality monitoring in agricultural streams. Monitoring helps detect nutrient content in the stream and directs towards the proper measures. The study offers valuable insights into improving treatment strategies using biochar, which is sustainable and environmentally friendly. It supports ongoing research into integrated and adaptive nutrient management solutions for agricultural streams.

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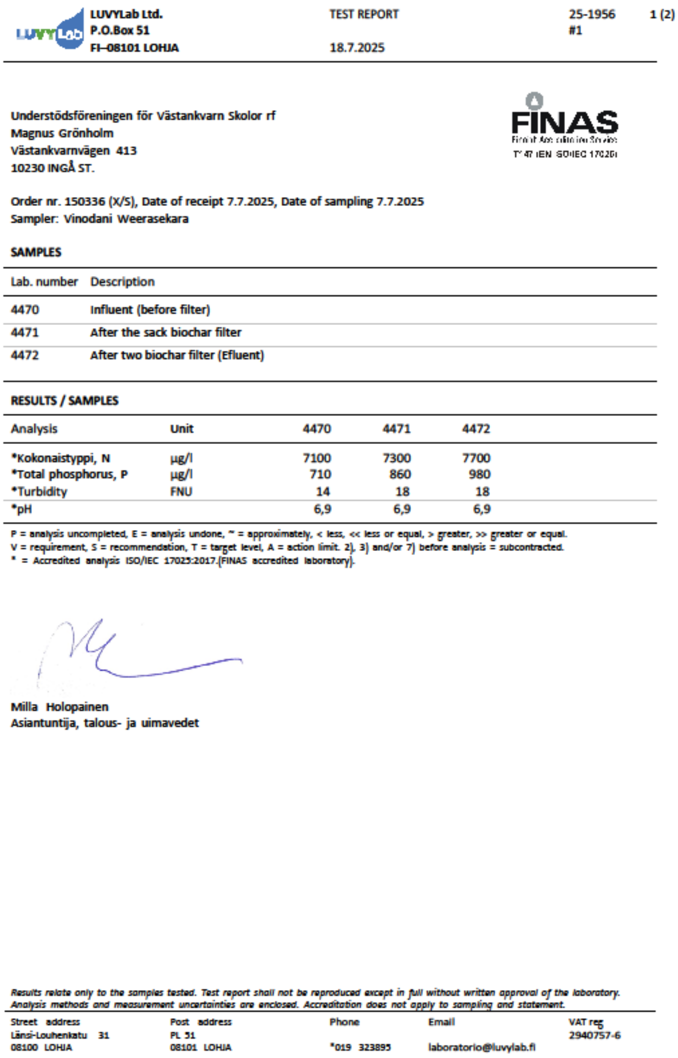
APPENDIX



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TEST REPORT

18.7.2025

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FINAS
Finnish Accreditation Service
T047 (EN ISO/IEC 17025)

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 150336 (X/S), Date of receipt 7.7.2025, Date of sampling 7.7.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
4470	Influent (before filter)
4471	After the sack biochar filter
4472	After two biochar filter (Efluent)

RESULTS / SAMPLES

Analysis	Unit	4470	4471	4472
*Kokonaistyppi, N	µg/l	7100	7300	7700
*Total phosphorus, P	µg/l	710	860	980
*Turbidity	FNU	14	18	18
*pH		6,9	6,9	6,9

P = analysis uncompleted, E = analysis undone, ~ = approximately, < less, << less or equal, > greater, >> greater or equal.
V = requirement, S = recommendation, T = target level, A = action limit. 2), 3) and/or 7) before analysis = subcontracted.
* = Accredited analysis ISO/IEC 17025:2017.(FINAS accredited laboratory).

Milla Holopainen
Asiantuntija, talous- ja uimavedet

Results relate only to the samples tested. Test report shall not be reproduced except in full without written approval of the laboratory.
Analysis methods and measurement uncertainties are enclosed. Accreditation does not apply to sampling and statement.

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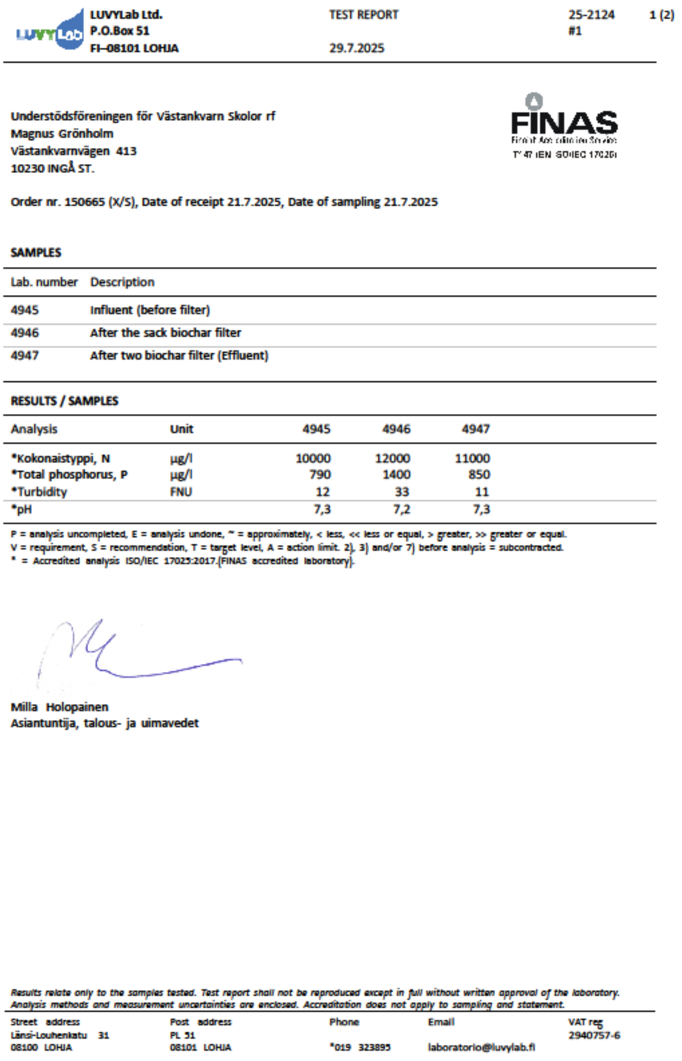

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FI–08101 LOHJA

TEST REPORT
29.7.2025

25-2124 1 (2)
#1

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 150665 (X/S), Date of receipt 21.7.2025, Date of sampling 21.7.2025

SAMPLES

Lab. number	Description
4945	Influent (before filter)
4946	After the sack biochar filter
4947	After two biochar filter (Effluent)

RESULTS / SAMPLES

Analysis	Unit	4945	4946	4947
*Kokonaistyppi, N	µg/l	10000	12000	11000
*Total phosphorus, P	µg/l	790	1400	850
*Turbidity	FNU	12	33	11
*pH		7,3	7,2	7,3

P = analysis uncompleted, E = analysis undone, ~ = approximately, < less, << less or equal, > greater, >> greater or equal.
V = requirement, S = recommendation, T = target level, A = action limit. 2), 3) and/or 7) before analysis = subcontracted.
* = Accredited analysis ISO/IEC 17025:2017.(FINAS accredited laboratory).

Milla Holopainen
Asiantuntija, talous- ja uimavedet

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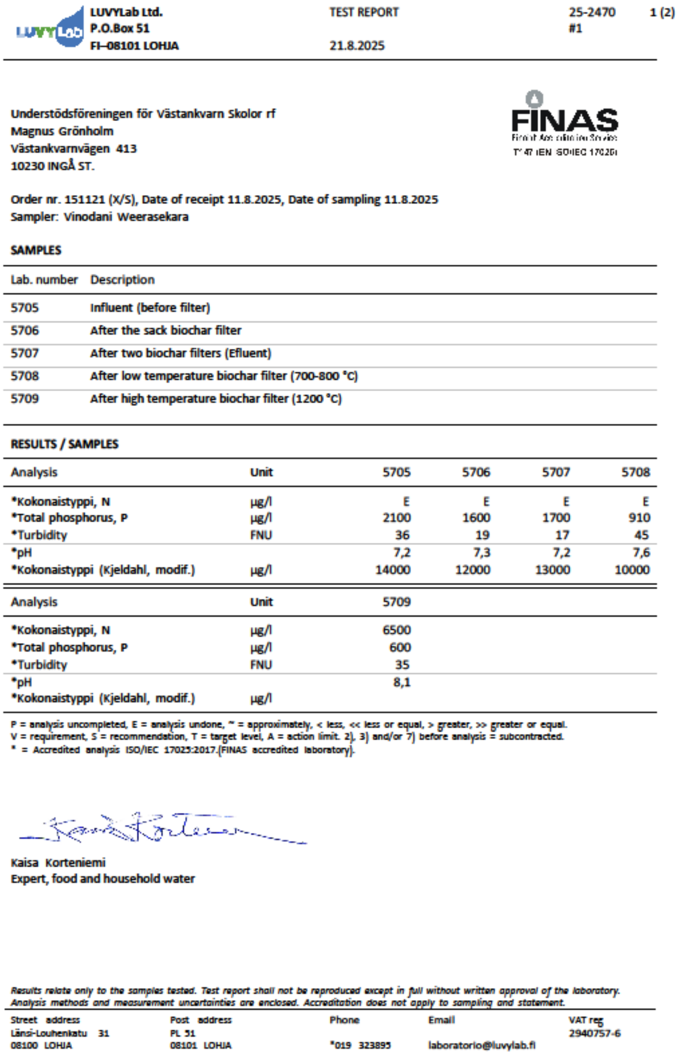
Analysis methods and measurement uncertainties are enclosed. Accreditation does not apply to sampling and statement.

Street address	Post address	Phone	Email	VAT reg
Länsi-Louhenkatu 31	PL 51			2940757-6
08100 LOHJA	08101 LOHJA	*019 323895	laboratorio@luvylab.fi	



LUVYLab Ltd.
P.O.Box 51
FI–08101 LOHJA

TEST REPORT
21.8.2025

25-2470 1 (2)
#1

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 151121 (X/S), Date of receipt 11.8.2025, Date of sampling 11.8.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
5705	Influent (before filter)
5706	After the sack biochar filter
5707	After two biochar filters (Efluent)
5708	After low temperature biochar filter (700-800 °C)
5709	After high temperature biochar filter (1200 °C)

RESULTS / SAMPLES

Analysis	Unit	5705	5706	5707	5708
*Kokonaistyppi, N	µg/l	E	E	E	E
*Total phosphorus, P	µg/l	2100	1600	1700	910
*Turbidity	FNU	36	19	17	45
*pH		7,2	7,3	7,2	7,6
*Kokonaistyppi (Kjeldahl, modif.)	µg/l	14000	12000	13000	10000

Analysis	Unit	5709
*Kokonaistyppi, N	µg/l	6500
*Total phosphorus, P	µg/l	600
*Turbidity	FNU	35
*pH		8,1
*Kokonaistyppi (Kjeldahl, modif.)	µg/l	

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Kaisa Korteniemi
Expert, food and household water

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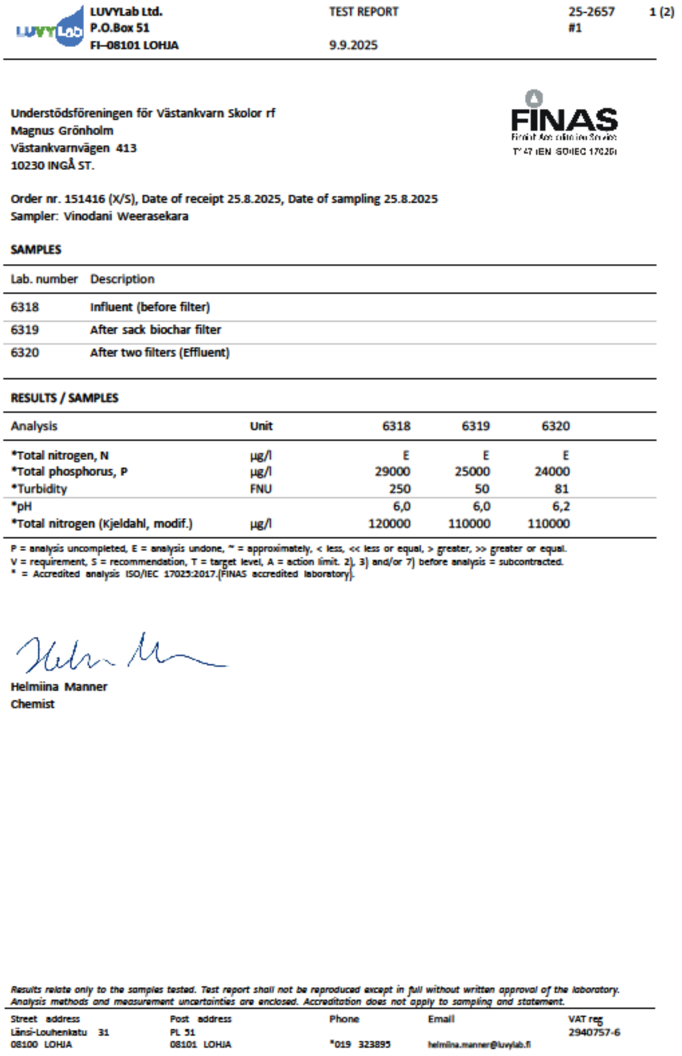
08100 LOHJA	08101 LOHJA	*019 323895	laboratorio@luvylab.fi	



LUVYLab Ltd.
P.O.Box 51
FI–08101 LOHJA

TEST REPORT
9.9.2025

25-2657 1 (2)
#1

FINAS
Finnish Accreditation Service
T147 (EN ISO/IEC 17025)

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 151416 (X/S), Date of receipt 25.8.2025, Date of sampling 25.8.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
6318	Influent (before filter)
6319	After sack biochar filter
6320	After two filters (Effluent)

RESULTS / SAMPLES

Analysis	Unit	6318	6319	6320
*Total nitrogen, N	µg/l	E	E	E
*Total phosphorus, P	µg/l	29000	25000	24000
*Turbidity	FNU	250	50	81
*pH		6,0	6,0	6,2
*Total nitrogen (Kjeldahl, modif.)	µg/l	120000	110000	110000

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Helmiina Manner
Chemist

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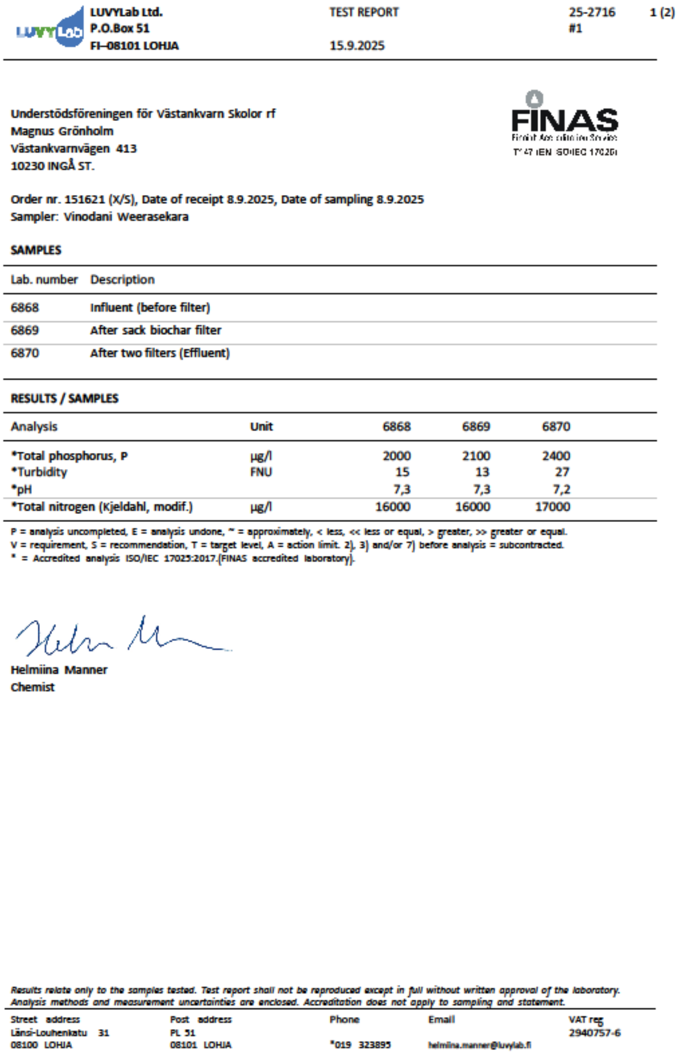

LUVYLab Ltd.
P.O.Box 51
FI–08101 LOHJA

TEST REPORT
15.9.2025

25-2716 1 (2)
#1

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 151621 (X/S), Date of receipt 8.9.2025, Date of sampling 8.9.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
6868	Influent (before filter)
6869	After sack biochar filter
6870	After two filters (Effluent)

RESULTS / SAMPLES

Analysis	Unit	6868	6869	6870
*Total phosphorus, P	µg/l	2000	2100	2400
*Turbidity	FNU	15	13	27
*pH		7,3	7,3	7,2
*Total nitrogen (Kjeldahl, modif.)	µg/l	16000	16000	17000

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Helmiina Manner
Chemist

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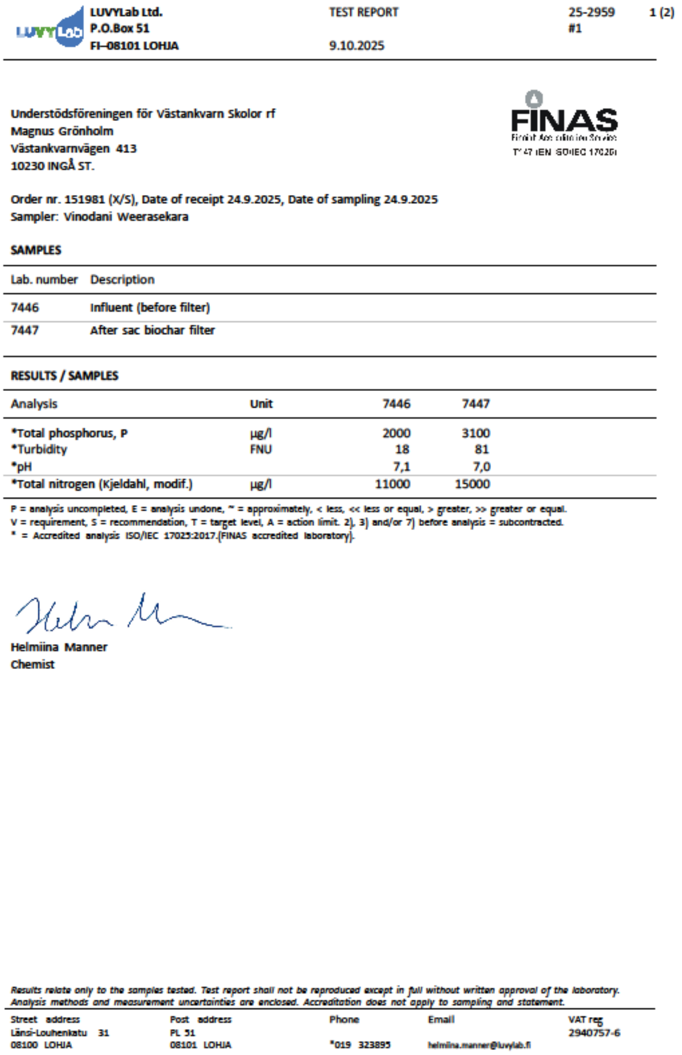
Länsi-Louhenkatu 31 08100 LOHJA	PL 51 08101 LOHJA	*019 323895	helmiina.manner@luvylab.fi	2940757-6



LUVYLab Ltd.
P.O.Box 51
FI–08101 LOHJA

TEST REPORT
9.10.2025

25-2959 1 (2)
#1

FINAS
Finnish Accreditation Service

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 151981 (X/S), Date of receipt 24.9.2025, Date of sampling 24.9.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
7446	Influent (before filter)
7447	After sac biochar filter

RESULTS / SAMPLES

Analysis	Unit	7446	7447
*Total phosphorus, P	µg/l	2000	3100
*Turbidity	FNU	18	81
*pH		7,1	7,0
*Total nitrogen (Kjeldahl, modif.)	µg/l	11000	15000

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Helmiina Manner
Chemist

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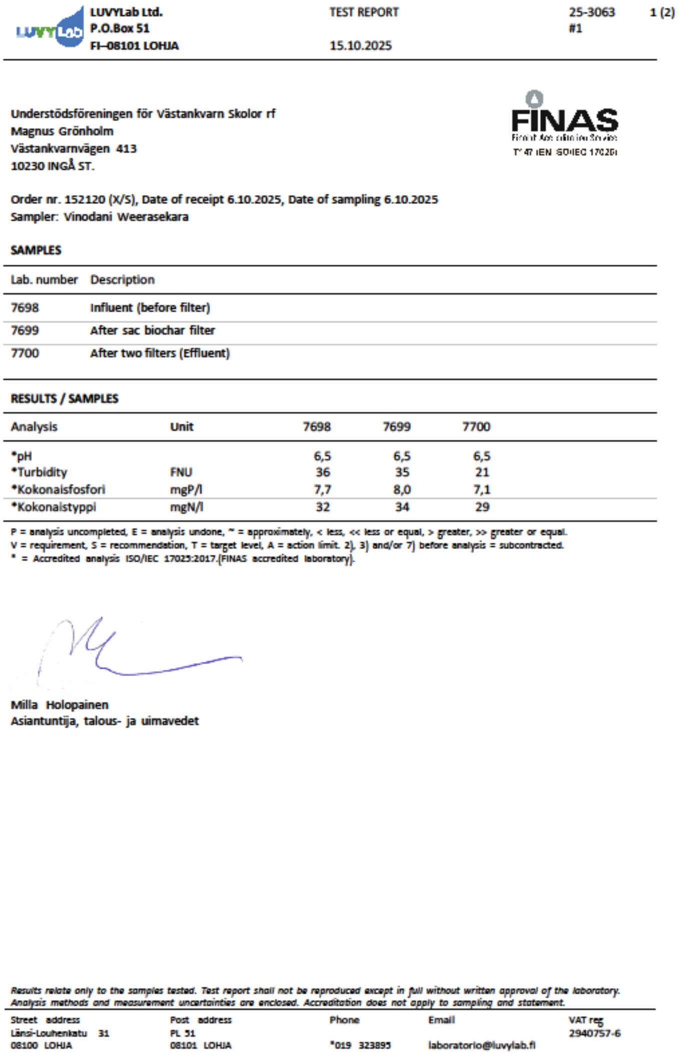
Länsi-Louhenkatu 31	PL 51			2940757-6
08100 LOHJA	08101 LOHJA	*019 323895	helmiina.manner@luvylab.fi	



LUVYLab Ltd.
P.O.Box 51
FI–08101 LOHJA

TEST REPORT
15.10.2025

25-3063 1 (2)
#1

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 152120 (X/S), Date of receipt 6.10.2025, Date of sampling 6.10.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
7698	Influent (before filter)
7699	After sac biochar filter
7700	After two filters (Effluent)

RESULTS / SAMPLES

Analysis	Unit	7698	7699	7700
*pH		6,5	6,5	6,5
*Turbidity	FNU	36	35	21
*Kokonaisfosfori	mgP/l	7,7	8,0	7,1
*Kokonaistyppi	mgN/l	32	34	29

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Milla Holopainen
Asiantuntija, talous- ja uimavedet

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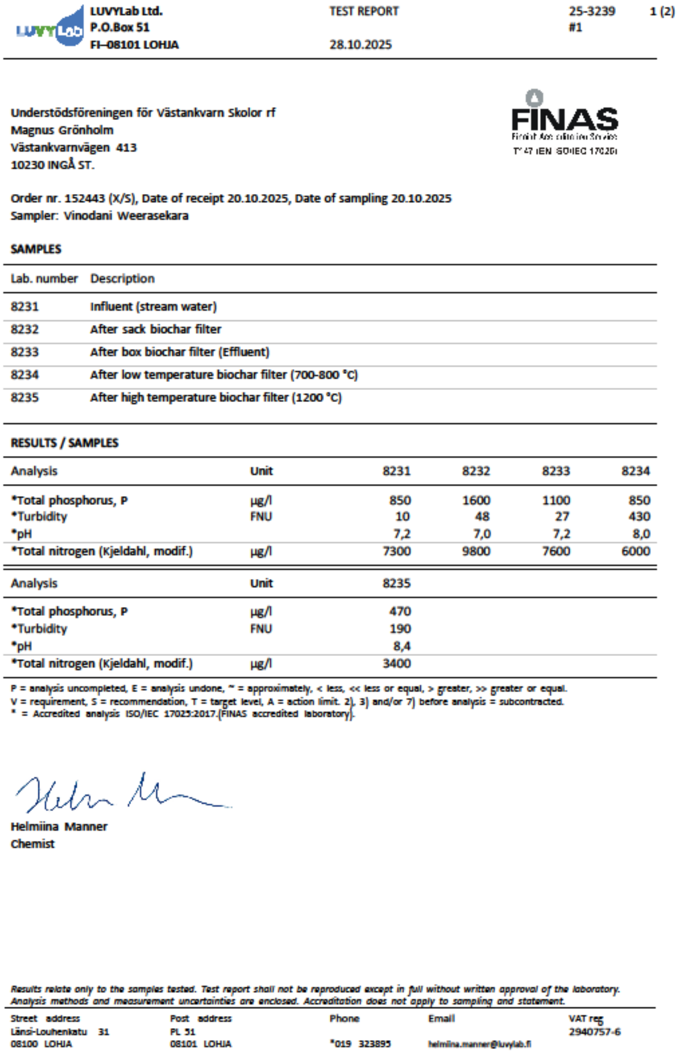

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FI–08101 LOHJA

TEST REPORT
28.10.2025

25-3239 1 (2)
#1

FINAS
Finnish Accreditation Service
T147 (EN ISO/IEC 17025)

Understödsföreningen för Västankvarn Skolor rf
Magnus Grönholm
Västankvarnvägen 413
10230 INGÅ ST.

Order nr. 152443 (X/S), Date of receipt 20.10.2025, Date of sampling 20.10.2025
Sampler: Vinodani Weerasekara

SAMPLES

Lab. number	Description
8231	Influent (stream water)
8232	After sack biochar filter
8233	After box biochar filter (Effluent)
8234	After low temperature biochar filter (700-800 °C)
8235	After high temperature biochar filter (1200 °C)

RESULTS / SAMPLES

Analysis	Unit	8231	8232	8233	8234
*Total phosphorus, P	µg/l	850	1600	1100	850
*Turbidity	FNU	10	48	27	430
*pH		7,2	7,0	7,2	8,0
*Total nitrogen (Kjeldahl, modif.)	µg/l	7300	9800	7600	6000

Analysis	Unit	8235
*Total phosphorus, P	µg/l	470
*Turbidity	FNU	190
*pH		8,4
*Total nitrogen (Kjeldahl, modif.)	µg/l	3400

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Helmiina Manner
Helmiina Manner
Chemist

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