

# Decentralized Wastewater Valorization with Floating Plant Systems

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## INTRODUCTION

The Philippines, with its 7,000+ islands, faces severe pressures on coastal ecosystems from climate change, overfishing, and eutrophication<sup>1</sup>. Untreated wastewater from markets and food industries among others contributes high nitrogen and phosphorus loads, driving algal blooms and oxygen depletion<sup>2</sup>. Centralized treatment infrastructure is scarce; most wastewater is discharged untreated or passes only through septic tanks, which remove solids but not nutrients<sup>3</sup>. Yet, these waste streams also contain valuable resources. Nutrient recovery can reduce environmental impacts while providing substitutes for mineral fertilizers and feed inputs such as soybean meal or fishmeal<sup>4</sup>. Floating macrophytes like *Azolla* and *Lemna*, with fast growth and high nutrient uptake, offer potential for decentralized wastewater valorization.

## CONCEPT

This thesis explores decentralized wastewater valorization by combining established pre-treatment processes with floating plant systems for nutrient recovery. The underlying concept is that wastewater from small-scale markets (here: Mandaue Public Market) and meat-processing facilities (here: CHV Food in Cebu-City) in the Philippines, while posing environmental and health risks due to high organic loads, nutrients, and occasional heavy metals, also represents a valuable resource stream. By integrating low-tech processes, both effluent quality and biomass production can be improved. The designed treatment train consisted of three steps: chemical pre-precipitation with  $FeCl_3$  to reduce turbidity, fats, and suspended solids, biological treatment with activated sludge to remove dissolved organic carbon (DOC) and convert ammonium to nitrate, and a final polishing stage with floating macrophytes, primarily *Lemna minor* and *Azolla filiculoides*, to recover residual nutrients into plant biomass. This approach was chosen to balance pollutant removal with the retention of plant-available nitrogen and phosphorus. The harvested biomass is envisioned for reuse as animal feed or fertilizer, provided heavy metal contents remain within safety limits.

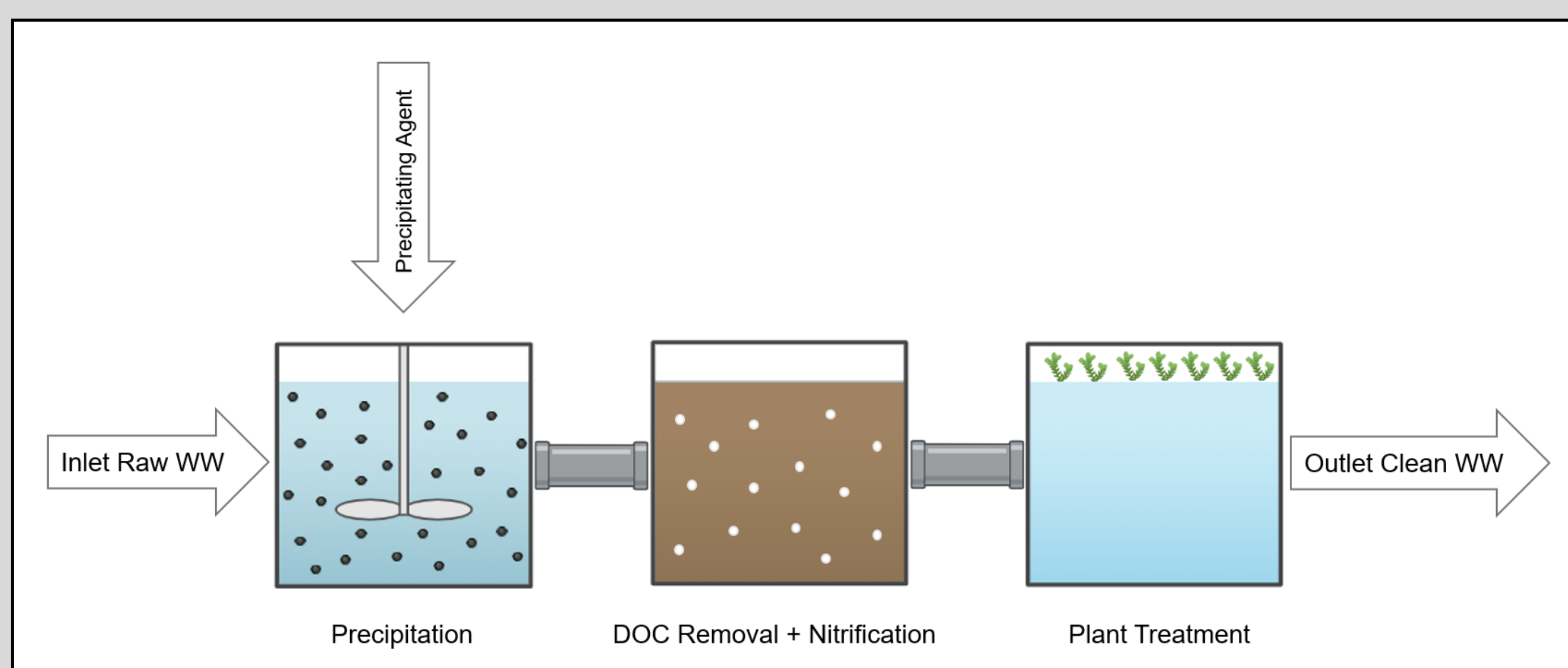


Figure 1. Suggested treatment cascade

Three research questions structured the study:

1. What are the key physical and chemical characteristics of wastewater from small-scale meat-processing facilities and public markets in the Philippines, and what infrastructural and spatial constraints affect the feasibility of decentralized treatment?
2. Which pre-treatment strategy best prepares wastewater for subsequent macrophyte-based polishing, in terms of reducing growth-inhibiting contents, maintaining nutrient availability, and resulting in measurable differences in plant growth?
3. To what extent can macrophytes such as *Azolla filiculoides* and *Lemna minor* take up nutrients from pre-treated wastewater, and how does their possible accumulation of heavy metals affect both biomass reuse and effluent safety?

By linking wastewater management to nutrient recovery and biomass production, this concept demonstrates a potential pathway for sustainable, small-scale solutions that support both environmental protection and circular resource use in Southeast Asia.

## RESULTS

The facility assessments revealed highly variable wastewater qualities. At Mandaue Public Market, effluent showed high turbidity with nitrate, phosphate and arsenic exceeding regulatory limits. At CHV Foods, the same nutrients and organic loads remained very high, also copper and arsenic were problematic. Neither facility's effluent complied with Philippine Class C water quality standards<sup>5</sup>. In laboratory-scale experiments with proxy wastewater, pre-precipitation using  $FeCl_3$  effectively reduced turbidity (80–95%) and phosphorus (up to 97%), while activated sludge treatment achieved 46–96% DOC removal and nitrification of ammonium to nitrate.

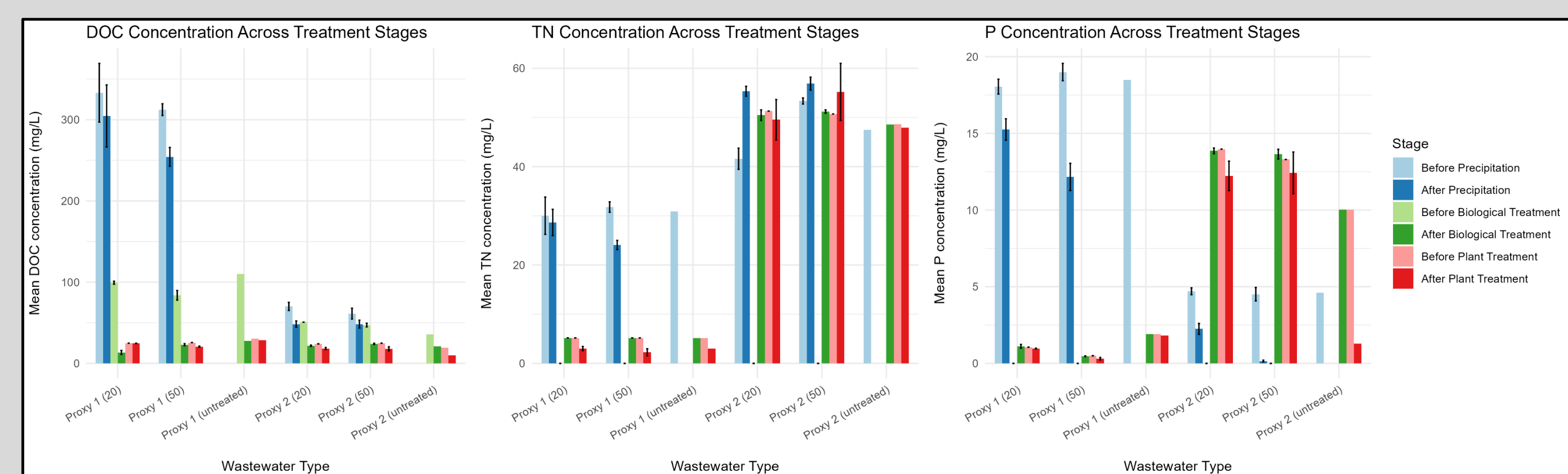


Figure 2. Development of DOC, total dissolved nitrogen and dissolved phosphorus across all treatment stages

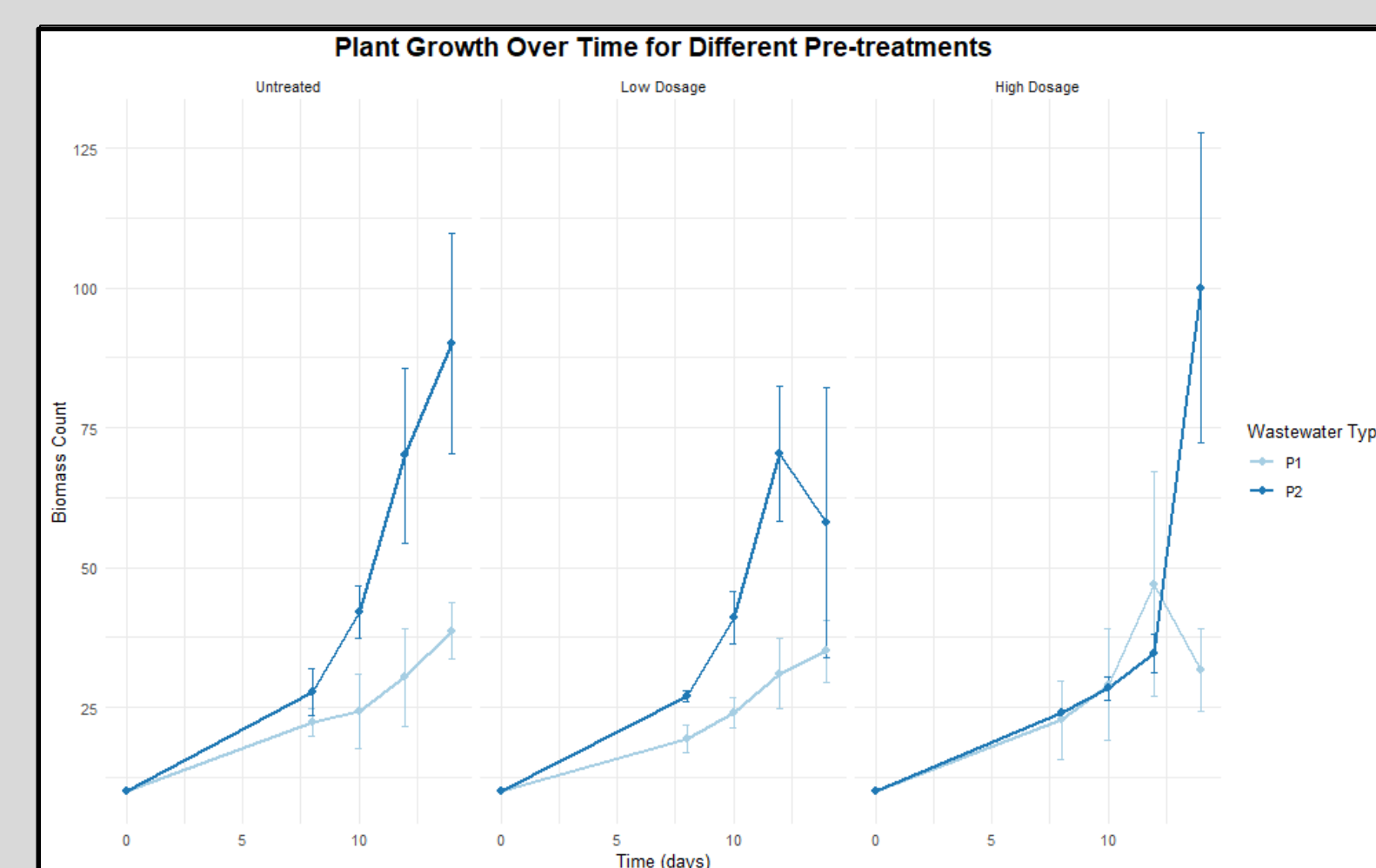


Figure 3. Plant growth by frond count

These steps not only reduced growth-inhibiting compounds but also improved nutrient availability for plant uptake. Growth trials confirmed that *Lemna minor* grew reliably in all treated wastewater types, whereas *Azolla filiculoides* was less robust. Doubling times varied widely: fastest growth occurred in Proxy 2 wastewater (3.2 days), where nitrate and phosphate were abundant.

Evidence of phosphorus “luxury uptake” was observed, with *Lemna* storing excess P in tissue. Heavy metals (Pb, Cu, Zn) accumulated in biomass but remained below fertilizer and most feed thresholds, except for arsenic. Overall, the treatment train demonstrated effective organic matter reduction and promising nutrient recovery through *Lemna* cultivation, but consistent compliance with regulatory limits for nitrogen, phosphorus, and certain heavy metals was not yet achieved.

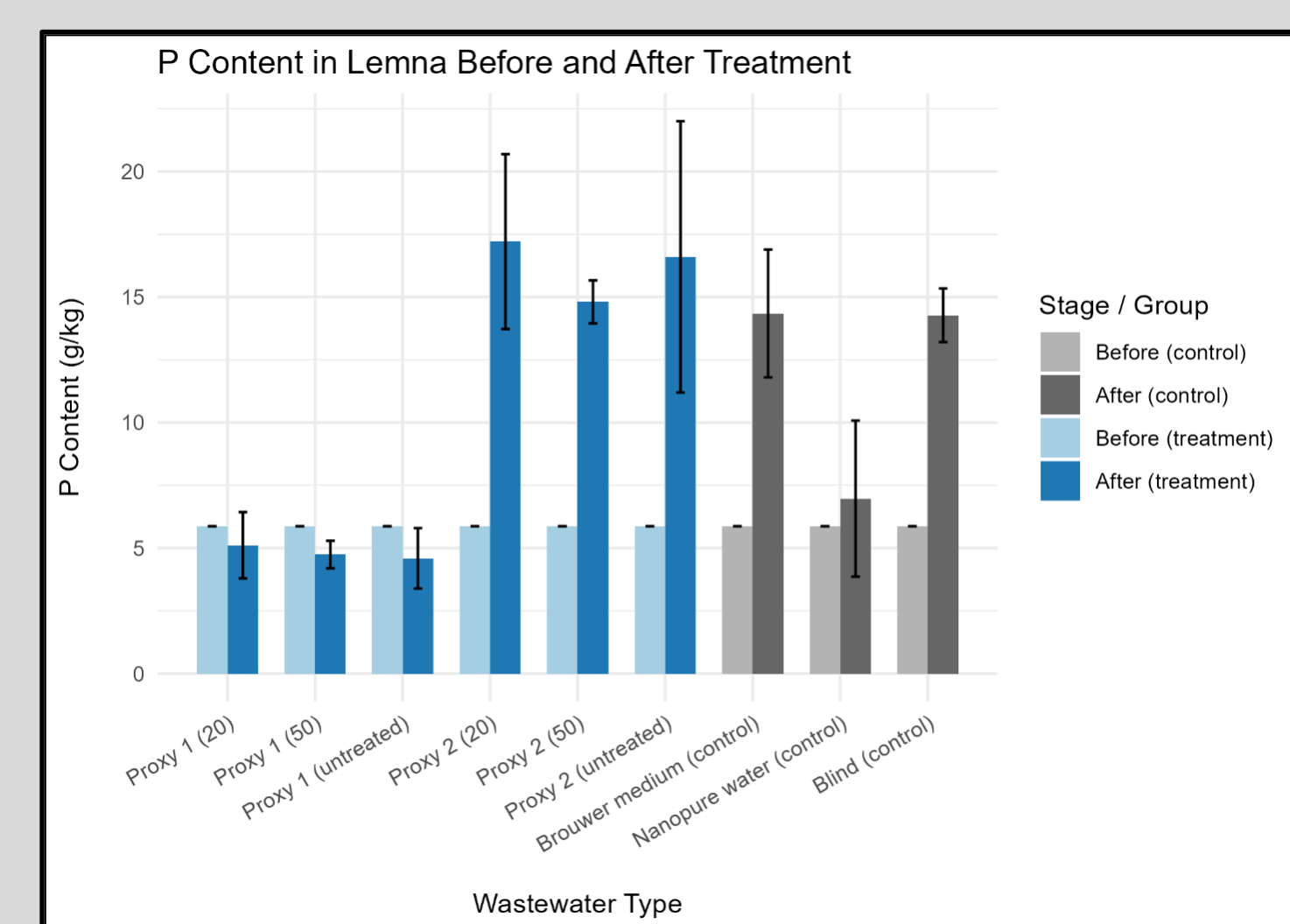


Figure 4. P uptake in *Lemna minor*

## CONCLUSION

This study demonstrates the potential of decentralized wastewater valorization through a combined treatment train of chemical precipitation, activated sludge, and macrophyte polishing. *Lemna minor* grew reliably on pre-treated effluents, confirming its suitability as a polishing step for nutrient-rich wastewater. While organic matter removal was effective, residual nitrogen and phosphorus concentrations remained above regulatory limits, showing that further optimization is needed for compliance. *Azolla filiculoides* was less robust under the tested conditions. Overall, this approach highlights how integrating low-tech processes with floating plants can improve effluent quality while generating biomass for reuse in circular resource systems.

FOR REFERENCES SCAN HERE:

