ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 11| Issue: 8| August 2025|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2025: 8.691 || ISI Value: 1.188

# PHYTOREMEDIATION OF MUNICIPAL WASTEWATER (Sewage) UTILIZING A FREE-FLOATING AQUATIC MACROPHYTE, *Lemna minor*

**Sangeeta L. Jadhav[1], Mohan G. Babare[2]**
[1]*Indian Institute of Food Science and Technology,Chhatrapati Sambhajinagar -431005(India).*
[2]*Dr. Babasaheb Ambedkar Marathwada University, Aurangabad-431004 (India).*

## ABSTRACT

*This study explores the use of Lemna minor, a free-floating aquatic plant, for phytoremediation of municipal wastewater from Chhatrapati Sambhajinagar, Maharashtra. Conducted over four months (April–July 2023), the experiment involved treating wastewater at varying concentrations (20% to 100%) using 200 g of fresh Lemna minor in controlled cement tanks. Key water quality parameters—such as pH, electrical conductivity (EC), total suspended and dissolved solids (TSS and TDS), biochemical and chemical oxygen demand (BOD and COD), along with nutrients like nitrates, phosphates, sulphates, chlorides, and nitrogen compounds—were analyzed before and after treatment.*

*The results indicated significant improvement in water quality. pH levels moved closer to neutral (6.5 to 7.2), and EC decreased by up to 497 µS/cm. Notable reductions were recorded in TSS (up to 59 mg/L), TDS (58 mg/L), BOD (60.8 mg/L), and COD (141 mg/L). Additionally, nutrient removal was effective, with significant decreases in nitrate, phosphate, ammoniacal nitrogen, and total nitrogen-helping to mitigate eutrophication risks.*

*The findings confirm Lemna minor's capacity to absorb both organic and inorganic pollutants, demonstrating its potential as a cost-effective, sustainable, and environmentally friendly solution for wastewater treatment. While results are promising, further optimization is recommended for handling higher pollutant loads. This study highlights phytoremediation as a viable green alternative to conventional wastewater treatment methods.*

**KEYWORDS:** *Phytoremediation, Lemna Minor, Municipal Wastewater, Nutrient Removal, Aquatic Macrophytes*

## INTRODUCTION

Rapid urbanization and industrialization have significantly increased the generation of municipal wastewater, posing a severe threat to aquatic ecosystems and public health. Conventional wastewater treatment methods, while effective, are often capital-intensive and energy-dependent, making them unsuitable for economically constrained or rural areas (Vymazal, 2010). As an alternative, nature-based solutions such as phytoremediation-the use of plants to remove, degrade, or contain environmental contaminants-have garnered increasing interest due to their cost-effectiveness, ecological sustainability, and ease of application (Ali et al., 2013).

Among the various plant-based remediation approaches, the use of aquatic macrophytes has proven particularly promising for the treatment of sewage and other wastewater sources. *Lemna minor*, commonly known as duckweed, is a small, free-floating aquatic plant widely recognized for its rapid growth rate, high nutrient uptake capacity, and adaptability to polluted environments (Zhao et al., 2015). Its ability to absorb and accumulate significant amounts of nitrogen (N), phosphorus (P), and various heavy metals makes it an ideal candidate for wastewater treatment (Verma and Suthar, 2015).

Several studies have demonstrated the effectiveness of *Lemna minor* in removing pollutants from domestic and industrial wastewater. For instance, Mo et al. (2016) reported significant reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total suspended solids (TSS) using *Lemna minor* in small-scale treatment systems. Furthermore, its potential for biomass recovery and subsequent use as animal feed or biofertilizer adds a valuable dimension to its application (Cheng and Stomp, 2009).

Despite the growing body of literature on duckweed-based remediation systems, localized research is essential to assess its efficiency under region-specific wastewater compositions and climatic conditions. This study aims to evaluate the phytoremediation potential of *Lemna minor* in treating municipal sewage, focusing on its efficiency in reducing key water quality parameters such as BOD, COD, total nitrogen, total phosphorus, and microbial load under controlled experimental conditions.

## MATERIALS AND METHODS

The present study investigated the phytoremediation potential of the free-floating aquatic macrophyte *Lemna minor* in treating domestic wastewater. The wastewater was collected from a pond situated near a bridge in the Itkheda area of Chhatrapati

Sambhajinagar, Maharashtra. The experimental period spanned the summer months, from April to July 2023, to ensure optimal plant growth and contaminant uptake, as temperature and light availability significantly influence the metabolic activity of aquatic macrophytes (Zhao et al., 2015).

A total of 200 grams (fresh weight) of *Lemna minor* was introduced into a rectangular cement tank measuring 195 cm in length, 145 cm in breadth, and 75 cm in depth. The tank was filled with untreated domestic wastewater, and the plants were allowed to grow under natural sunlight conditions for a period of seven days. Similar experimental setups using duckweed in outdoor tanks or constructed wetlands have been employed successfully in previous studies to assess phytoremediation efficiency under semi-controlled conditions (Mo et al., 2016; Vymazal, 2010).

The physicochemical parameters of the wastewater were analyzed both before and after the treatment period. Standard methods for water and wastewater analysis, as outlined by the American Public Health Association (APHA, 1989), were followed to ensure reliability and consistency of the data. Parameters assessed included pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sulphates, phosphates, and nitrates.

## RESULTS AND DISCUSSION

### A. Status Before Treatment

The initial physicochemical analysis of municipal sewage across five concentration sets (20% to 100%) revealed a consistent increase in pollutant load with rising sewage concentration, indicating high levels of contamination in untreated domestic wastewater (Table 1).

**pH and Electrical Conductivity (EC)**

The pH values ranged from 6.2 in Set I (20%) to 6.6 in Set V (100%), suggesting slightly acidic conditions across all concentrations. These values fall within the typical range reported for raw municipal wastewater, which is often slightly acidic to neutral due to the presence of organic matter and metabolic by-products (Vymazal, 2010). Electrical conductivity, a measure of ionic concentration, increased steadily from 262 µS/cm in Set I to 812 µS/cm in Set V, reflecting higher concentrations of dissolved inorganic salts, primarily chlorides, sulphates, and ammonium ions.

**Solids (TSS, TDS, TS)**

A significant rise in Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) was observed with increasing sewage concentration. TSS increased from 26 mg/L (Set I) to 125 mg/L (Set V), while TDS rose from 42 mg/L to 209 mg/L. These values indicate a progressively higher burden of organic and inorganic particulates and dissolved materials in the wastewater. Elevated solid content is a characteristic feature of untreated municipal sewage and often contributes to turbidity, reduced light penetration, and oxygen depletion in receiving water bodies (Ali et al., 2013).

**Oxygen-Demanding Parameters (BOD and COD)**

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) serve as key indicators of organic pollution. BOD increased from 21 mg/L (Set I) to 106 mg/L (Set V), while COD rose from 45 mg/L to 215 mg/L. These levels significantly exceed the permissible discharge limits set by environmental regulatory agencies, confirming the presence of substantial biodegradable and non-biodegradable organic matter (Zhao et al., 2015). The high BOD and COD values in the undiluted sewage (Set V) reflect a strong oxygen demand, which can be detrimental to aquatic life if discharged untreated.

**Nutrients (Nitrogen and Phosphorus Forms)**

Nitrogen compounds, including nitrate ($NO_3^-$), ammoniacal nitrogen ($NH_4^+$-N), and total nitrogen, showed a marked increase with sewage concentration. Nitrate levels rose from 0.1 mg/L (Set I) to 3.1 mg/L (Set V), while ammoniacal nitrogen increased from 4 mg/L to 18 mg/L, and total nitrogen from 11 mg/L to 52.5 mg/L. Phosphate ($PO_4^{3-}$) concentrations ranged from 2.1 mg/L to 12 mg/L across the five sets. Such elevated nutrient levels are typical of domestic sewage due to detergents, food waste, and human excreta and are known to contribute to **eutrophication** when discharged into natural water bodies (Verma & Suthar, 2015).

**Sulphates and Chlorides**

Sulphate concentrations increased from 14.9 mg/L to 75 mg/L, and chloride levels ranged from 7.5 mg/L to 41 mg/L. These ions commonly originate from household cleaning agents, soaps, and metabolic waste and contribute to the **salinity** and ionic load of sewage (Cheng & Stomp, 2009). While not directly toxic at these levels, their accumulation can disrupt the osmotic balance in freshwater organisms.

**Overall Pollution Profile**

The overall trend across all parameters demonstrates a clear correlation between sewage concentration and pollutant load. Set V (100% concentration) represents the actual strength of untreated municipal sewage, and its high levels of BOD, COD, nutrients, and solids highlight the urgent need for effective treatment methods. The data justify the selection of *Lemna minor* for phytoremediation, given its known efficiency in assimilating nutrients and reducing organic load in contaminated water (Mo et al., 2016; Vymazal, 2010).
This baseline assessment provides a critical reference for evaluating the post-treatment efficiency of *Lemna minor* in reducing the pollution load of municipal wastewater.

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 11| Issue: 8| August 2025|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2025: 8.691 || ISI Value: 1.188

**Table 1: Initial Physicochemical characteristics of Municipal Sewage**

| Treatment Parameter | Unit | Set I (Conc-20%) | Set II (Conc-40%) | Set III (Conc-60%) | Set IV (Conc-80%) | Set V (Conc-100%) |
|---|---|---|---|---|---|---|
| **pH** | | 6.2 | 6.3 | 6.4 | 6.5 | 6.6 |
| **EC** | (µS/cm) | 262 | 321 | 490 | 647 | 812 |
| **TSS** | mg/L | 26 | 50 | 74 | 103 | 125 |
| **TDS** | mg/L | 42 | 80 | 122 | 165 | 209 |
| **TS** | mg/L | | | | | |
| **BOD** | mg/L | 21 | 43 | 64 | 85 | 106 |
| **COD** | mg/L | 45 | 91 | 129 | 181 | 215 |
| **$NO_3$** | mg/L | 0.1 | 0.5 | 1.3 | 1.6 | 3.1 |
| **$PO_4$** | mg/L | 2.1 | 4.8 | 7.3 | 10.1 | 12 |
| **$SO_4$** | mg/L | 14.9 | 29.8 | 44 | 61 | 75 |
| **$Cl^-$** | mg/L | 7.5 | 15.2 | 21.8 | 34 | 41 |
| **Amm Nitrogen** | mg/L | 4 | 7.8 | 12.2 | 14.3 | 18 |
| **Total Nitrogen** | mg/L | 11 | 21.5 | 32 | 42.1 | 52.5 |

**Final Physicochemical characteristics of Municipal wastewater treatment**

| Treatment Parameter | Unit | Set I (Conc-20%) | Set II (Conc-40%) | Set III (Conc-60%) | Set IV (Conc-80%) | Set V (Conc-100%) |
|---|---|---|---|---|---|---|
| **pH** | | 6.5 | 6.9 | 7 | 7.1 | 7.2 |
| **EC** | (µS/cm) | 170 | 140 | 230 | 289 | 315 |
| **TSS** | mg/L | 17 | 22 | 51 | 62 | 66 |
| **TDS** | mg/L | 27 | 43 | 83 | 107 | 158 |
| **TS** | mg/L | | | | | |
| **BOD** | mg/L | 7.7 | 15 | 19.1 | 24.2 | 53.8 |
| **COD** | mg/L | 17 | 34 | 53 | 64 | 74 |
| **$NO_3$** | mg/L | 0 | 0 | 0 | 0.2 | 0.5 |
| **$PO_4$** | mg/L | 0.4 | 1.3 | 2.1 | 4.7 | 4.9 |
| **$SO_4$** | mg/L | 5.1 | 10.2 | 15 | 19.9 | 27 |
| **$Cl^-$** | mg/L | 5.1 | 11 | 14.5 | 21.2 | 29 |
| **Amm. Nitrogen** | mg/L | 1.1 | 2.4 | 3.5 | 4.2 | 7 |
| **Total Nitrogen** | mg/L | 3.1 | 7 | 9.1 | 13.2 | 16.1 |

**Status after Treatment**

The post-treatment analysis of municipal wastewater with the aquatic macrophyte *Lemna minor* showed a substantial reduction in various physicochemical parameters across all concentration sets (20%–100%), confirming its effectiveness in phytoremediation of sewage water (Table 2).

**pH and Electrical Conductivity (EC)**

Post-treatment pH values increased slightly from their initial readings, ranging from 6.5 (Set I) to 7.2 (Set V), suggesting a shift towards neutral or slightly alkaline conditions. This shift is commonly observed in phytoremediation systems due to the uptake of acidic compounds and release of hydroxyl ions during nutrient absorption by plants (Vymazal, 2010). Electrical conductivity (EC) values declined significantly, particularly in the higher concentration sets—dropping from 812 µS/cm to 315 µS/cm in Set V, indicating effective removal of dissolved ions, likely due to uptake of nutrients and salts by *Lemna minor* (Mo et al., 2016; Zhao et al., 2015).

**Solids (TSS, TDS)**

Total Suspended Solids (TSS) were reduced by 25% to 50% across all sets, with the highest reduction in Set II (from 50 mg/L to 22 mg/L). Similarly, Total Dissolved Solids (TDS) showed a marked decline—from 209 mg/L to 158 mg/L in the 100% concentration (Set V). The reduction in both TSS and TDS is attributed to the ability of duckweed to trap suspended particles and absorb dissolved nutrients from the water (Ali et al., 2013;

Verma & Suthar, 2015). These findings align with earlier research where *Lemna minor* was shown to effectively reduce turbidity and improve water clarity.

**Organic Load (BOD and COD)**
A notable decrease in Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) was observed, signifying efficient removal of organic pollutants. BOD dropped from 106 mg/L to 53.8 mg/L (49.2% reduction) in Set V and from 21 mg/L to 7.7 mg/L in Set I (63.3% reduction). COD showed a more pronounced reduction, particularly in Set V (from 215 mg/L to 74 mg/L; 65.6% reduction). These reductions suggest enhanced microbial degradation of organic matter facilitated by the oxygen-releasing properties of duckweed and its ability to assimilate organic nutrients (Cheng & Stomp, 2009; Mo et al., 2016).

**Nutrient Removal (Nitrogen and Phosphorus)**
One of the most significant findings of this study was the marked decrease in nitrogen and phosphorus species post-treatment. Nitrate ($NO_3^-$) levels were reduced to negligible values (0–0.5 mg/L) across all sets, indicating near-complete uptake, especially in lower concentrations. Ammoniacal nitrogen dropped from 18 mg/L to 7 mg/L in Set V (61% reduction), and total nitrogen from 52.5 mg/L to 16.1 mg/L (69.3% reduction). Phosphate ($PO_4^{3-}$) levels also dropped significantly, with the highest decrease observed in Set I (from 2.1 mg/L to 0.4 mg/L; 81% reduction). The nutrient absorption capacity of *Lemna minor* is well-documented, as it utilizes nitrogen and phosphorus for growth, thus preventing eutrophication in receiving water bodies (Zhao et al., 2015; Verma & Suthar, 2015).

**Sulphates and Chlorides**
Sulphate concentrations declined from 75 mg/L to 27 mg/L (64% reduction), and chloride levels from 41 mg/L to 29 mg/L (29.3% reduction) in the 100% concentration set. This reduction may result from plant uptake and sedimentation processes facilitated by the root structure of *Lemna minor* (Ali et al., 2013). Although sulphates and chlorides are not usually toxic at these levels, their reduction helps improve the overall ionic balance of the treated water.

**Overall Performance and Implications of treatment**
The results clearly demonstrate the phytoremediation potential of *Lemna minor* in improving wastewater quality, particularly in terms of reducing nutrient loads, organic matter, and suspended solids. The plant's high growth rate and adaptability allow it to assimilate large quantities of pollutants, making it a viable option for decentralized and low-cost wastewater treatment, especially in developing regions (Cheng & Stomp, 2009; Vymazal, 2010).

These findings reinforce earlier studies that suggest duckweed-based systems as eco-friendly and sustainable alternatives to conventional wastewater treatment methods (Mo et al., 2016; Zhao et al., 2015). However, the efficiency was slightly lower in higher concentration sets (Set V), indicating that very high pollutant loads may require extended retention times or integrated treatment approaches for optimal results.

**Reduction/Change in Physicochemical characteristics of Municipal wastewater treatment**

| Treatment Parameter | Unit | Set I (Conc-20%) | Set II (Conc-40%) | Set III (Conc-60%) | Set IV (Conc-80%) | Set V (Conc-100%) |
|---|---|---|---|---|---|---|
| **pH** | | 0.3 | 0.6 | 0.6 | 0.6 | 0.6 |
| **EC** | (µS/cm) | 92 | 181 | 260 | 358 | 497 |
| **TSS** | mg/L | 9 | 28 | 23 | 41 | 59 |
| **TDS** | mg/L | 15 | 37 | 39 | 58 | 51 |
| **TS** | mg/L | | | | | |
| **BOD** | mg/L | 13.3 | 28 | 44.9 | 60.8 | 52.2 |
| **COD** | mg/L | 28 | 57 | 76 | 117 | 141 |
| **$NO_3$** | mg/L | 0.1 | 0.5 | 1.3 | 1.4 | 2.6 |
| **$PO_4$** | mg/L | 1.7 | 3.5 | 5.2 | 5.4 | 7.1 |
| **$SO_4$** | mg/L | 9.8 | 19.6 | 29 | 41.1 | 48 |
| **$Cl^-$** | mg/L | 2.4 | 4.2 | 7.3 | 12.8 | 12 |
| **Amm. Nitrogen** | mg/L | 2.9 | 5.4 | 8.7 | 10.1 | 11 |
| **Total Nitrogen** | mg/L | 7.9 | 14.5 | 22.9 | 28.9 | 36.4 |

**Change Noticed**
The overall changes in physicochemical characteristics of municipal wastewater after treatment with *Lemna minor* clearly demonstrate the plant's substantial capacity for pollutant removal across different concentration sets (20% to 100%).

**pH Changes**
The pH values showed a slight increase ranging from 0.3 to 0.6 units across all sets, shifting wastewater conditions closer to neutral. This moderate pH change aligns with findings from Vymazal (2010), who noted that phytoremediation with

duckweed typically buffers the pH by uptake of acidic and basic ions, promoting a more balanced aquatic environment conducive to microbial activity and plant growth.

**Electrical Conductivity (EC)**
Electrical conductivity decreased significantly, with reductions between 92 µS/cm in the lowest concentration (Set I) and 497 µS/cm in the highest concentration (Set V). This decline indicates a notable decrease in dissolved salts and ions due to absorption by *Lemna minor*, consistent with previous reports highlighting duckweed's efficiency in ionic nutrient uptake (Mo et al., 2016; Zhao et al., 2015).

**Solids Reduction (TSS and TDS)**
Total Suspended Solids (TSS) removal varied from 9 mg/L in Set I to 59 mg/L in Set V, while Total Dissolved Solids (TDS) reduction ranged from 15 mg/L to 58 mg/L. These removals are attributable to *Lemna minor*'s ability to physically trap suspended particles and biochemically assimilate dissolved organic and inorganic matter (Ali et al., 2013). Reduction in solids enhances water clarity and quality, reducing turbidity and sedimentation risks.

**Organic Load Reduction (BOD and COD)**
Significant decreases in BOD (13.3 mg/L to 60.8 mg/L) and COD (28 mg/L to 141 mg/L) were observed across the increasing concentrations. These reductions indicate that *Lemna minor* effectively removes biodegradable and non-biodegradable organic matter, lowering oxygen demand and improving water quality. This effect supports findings by Cheng and Stomp (2009), who emphasized duckweed's role in mitigating organic pollution through nutrient assimilation and oxygenation.

**Nutrient Removal (Nitrogen and Phosphorus)**
Reductions in nitrate ($NO_3^-$) ranged from 0.1 mg/L in Set I to 2.6 mg/L in Set V, while phosphate ($PO_4^{3-}$) declined between 1.7 mg/L and 7.1 mg/L. Ammoniacal nitrogen and total nitrogen also showed significant decreases, with maximum reductions of 11 mg/L and 36.4 mg/L, respectively, in Set V. The uptake of these nutrients is critical for controlling eutrophication in natural water bodies, a process well-documented in literature on *Lemna minor*'s phytoremediation capabilities (Verma & Suthar, 2015; Zhao et al., 2015).

**Sulphates and Chlorides Reduction**
Sulphate concentrations decreased by up to 48 mg/L in the highest concentration set, while chloride levels dropped by up to 12 mg/L. Though these ions are less toxic at observed concentrations, their removal contributes to the overall improvement in water chemistry and ionic balance (Ali et al., 2013).

**Summary and Implications**
The data strongly support the use of *Lemna minor* as an effective, low-cost, and environmentally friendly option for treating municipal wastewater. The significant reductions in organic pollutants, nutrients, and solids demonstrate the plant's multi-faceted ability to improve water quality. These results are consistent with earlier research, confirming the suitability of duckweed-based treatment systems for decentralized wastewater management (Mo et al., 2016; Vymazal, 2010).

Future studies could explore the optimization of retention times and plant density to maximize pollutant removal efficiency, especially at higher sewage concentrations where reductions were somewhat less pronounced.

## CONCLUSION
The present study demonstrates that *Lemna minor*, a free-floating aquatic macrophyte, is highly effective in the phytoremediation of municipal wastewater. Across varying concentrations (20% to 100%), *Lemna minor* significantly improved the quality of sewage water by reducing key physicochemical parameters including BOD, COD, total suspended solids (TSS), total dissolved solids (TDS), nitrates, phosphates, ammoniacal nitrogen, and total nitrogen.

The pH shifted towards neutrality, and electrical conductivity decreased substantially, indicating effective removal of dissolved salts and pollutants. Organic load reductions were notable, with BOD and COD decreased by up to 63% and 66% respectively, highlighting the plant's ability to assimilate organic matter and enhance microbial degradation. Nutrient uptake by *Lemna minor* effectively lowered nitrogen and phosphorus concentrations, crucial for preventing eutrophication in natural water bodies.

These results align well with existing literature, confirming the feasibility of using *Lemna minor* as an eco-friendly, low-cost, and sustainable method for municipal wastewater treatment. While pollutant removal efficiency was slightly lower at the highest sewage concentrations, the overall performance of *Lemna minor* suggests its potential for integration into decentralized wastewater treatment systems, especially in resource-limited settings.

Future research may focus on optimizing operational parameters such as retention time, biomass density, and potential combination with other treatment technologies to enhance treatment efficiency further.

## REFERENCES
1. *APHA. (1989).* Standard methods for the examination of water and wastewater *(17th ed.). American Public Health Association.*
2. *Ali, H., Khan, E., & Sajad, M. A. (2013). Phytoremediation of heavy metals – concepts and applications.* Chemosphere, 91*(7), 869–881. https://doi.org/10.1016/j.chemosphere.2013.01.075*
3. *Cheng, J. J., & Stomp, A. M. (2009). Growing duckweed to recover nutrients from wastewaters and for production of fuel ethanol and animal feed.* Clean–Soil, Air, Water, 37*(1), 17–26. https://doi.org/10.1002/clen.200800210*

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 11| Issue: 8| August 2025|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2025: 8.691 || ISI Value: 1.188

4. *Mo, L., Zhang, Y., Zhang, W., & He, C. (2016). Removal of pollutants from municipal wastewater by duckweed (*Lemna minor*).* Ecological Engineering, 94*, 238–243. https://doi.org/10.1016/j.ecoleng.2016.05.075*
5. *Verma, A. K., & Suthar, S. (2015). Lead and cadmium removal through duckweed (*Lemna minor*) from artificially contaminated wastewater: A laboratory study.* Environmental Technology & Innovation, 3*, 107–114. https://doi.org/10.1016/j.eti.2015.02.002*
6. *Vymazal, J. (2010). Constructed wetlands for wastewater treatment.* Water, 2*(3), 530–549. https://doi.org/10.3390/w2030530*
7. *Zhao, Y., Fang, Y., Jin, Y., & Huang, J. (2015). Nutrient removal by* Lemna minor *in treating wastewater: A review.* Desalination and Water Treatment, 57*(33), 15494–15503. https://doi.org/10.1080/19443994.2015.1077167*