Utilizing Spirogyra grevilleana as a Phytoremediatory Agent for Reduction of Limnetic Nutrients and Escherichia coli Concentrations

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Introduction

One of the most widespread global issues of the twenty-first century is scarcity of clean drinking water. Lakes and rivers worldwide are becoming contaminated by chemical and biological pollutants, such as Escherichia coli, thus decreasing potability of the water. Overuse of fertilizers and subsequent runoff have led to increased E. coli and nutrient levels in many lakes and rivers worldwide. Consequently, these sources are highly polluted by increased concentrations of E. coli, nitrates, and phosphates. Implementing sustainable and affordable methods of bioremediation and phytoremediation is critical to providing clean drinking water to global communities.

This study uses Spirogyra grevilleana, a species of filamentous green algae, as a potential algal filter to naturally decrease the effects of E. coli and dissolved nutrients in freshwaters. There are over 400 species of the genus Spirogyra worldwide, making this genus ideal for global applications. Spirogyra spp. reduce bacterial levels of E. coli and other aquatic bacteria by reducing nutrient levels needed to sustain bacterial populations, and also by secreting antibacterial secondary metabolites into the water.

Based on prior experimentation and research, S. grevilleana has shown to improve water quality in freshwater lakes. The construction of an Algal Filtration Device containing S. grevilleana as an algal filter could provide a nonchemical and sustainable solution to increased E. coli, nitrates, and phosphate levels.

Methodology

16.0 ± 0.1 L samples of water were collected from a 2.32 ha freshwater lake in Atlanta, Georgia, USA. The baseline dissolved oxygen was measured using a PASCO dissolved oxygen meter (n=1) that was calibrated with the Winkler Method. The baseline pH was measured using a Hach pH meter (n=1) and the nitrate-nitrogen and phosphate levels were measured by a Hach handheld DR690 photometric colorimeter (n=3). The baseline E. coli levels were measured using a plate method (n=3) including incubation for 48 hours at 35.0 ± 1.0°C, as detailed in the US EPA Method 1604. Each sample was outfitted with a pump and an Algal Filtration Device. Lighting was provided 16 hr d⁻¹ to simulate sunlight in the laboratory setting. The pumps were activated and run continuously throughout the experiment. The samples were monitored over three weeks with E. coli tested twice per week and the other indicators tested three times per week using the same experimental methods as the baseline testing.

Summary and Conclusions

The lab-tested filtration device resulted in 100% reduction in E. coli levels, as well as 23% reduction in nitrate levels and 30% reduction in phosphate levels. Use of S. grevilleana as an algal filter is an effective method of E. coli and nutrient reduction in freshwater lakes. The Algal Filtration Device is sustainable, economical, and portable, making this approach suitable to mitigate pollution and to improve access to clean drinking water sources.

Comparing Results to US EPA Potable Water Standards

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EPA Standard</th>
<th>This Experiment</th>
<th>Analysis</th>
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</thead>
<tbody>
<tr>
<td>Nitrates</td>
<td>≤10 mg L⁻¹</td>
<td>2.93 mg L⁻¹</td>
<td>In Range</td>
</tr>
<tr>
<td>Phosphates</td>
<td>≤0.05 mg L⁻¹</td>
<td>0.14 mg L⁻¹</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.5 - 8.5</td>
<td>6.5 - 8.5</td>
<td>High</td>
</tr>
</tbody>
</table>

Figure 6: Potential for Production of Potable Water. Overall, the resultant water is potable compared to US EPA potable water standards. pH is slightly elevated but does not affect potability. pH levels could be adjusted by needeed using a buffer, such as Sodium Phosphate (Na₂PO₄). Utilization of this algal filtration device to remediate water collected from polluted freshwater lakes could potentially provide access to water for communities currently lacking close proximity to potable water.

Figure 7: Future Applications of the Algal Filtration Device. Potential usage for the Algal Filtration Device includes employing multiple devices to filter a freshwater lake to remove E. coli and to reduce nitrate and phosphate levels. The number of devices installed would be dependent on lake volume. During lake filtration, an effluent tube containing numerous Algal Filtration Devices would remove a portion of water for additional filtration before being deposited into a potable water reservoir for connection to community pipes or wells for localized sources of drinking water.

$$t \left( 1 - \ln F - \frac{V}{F} \right) \ln V = \frac{V}{Q} \int_{0}^{F} \left( \frac{V}{F} - \ln V + \ln F - F \frac{F}{t \ln V - t} \right) - t$$

Figure 8: Equation 1 for Scalability. This equation could be used to scale filtration effects of the Algal Filtration Device for any given volume of water. In the equation, t is time (day), V is volume (m³), and F is the flow rate integrated from time 0 to time t (m³). $F = \int_{t}^{Q} Q dt$, where Q = Q(t).

Figure 9: Equation 2 for Scalability of Multiple Devices. This equation allows for multiple devices to be figured into Equation 1 (Figure 8). Q is the total volumetric flow rate comprised of multiple individual filters (Q). F is the integrated flow rate from Equation 1.

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Affiliated Citations

