What I got in the course:

ENV. AND SOC. SL in ENGLISH ×

Session	Candidate	Category
MAY 2025	**ljg236**	**DIPLOMA**

Grade	Total scaled moderated mark	Lower grade boundary mark	Upper grade boundary mark	Marks required for grade to increase
5	52	46	56	5

Internal Assessment
Environmental Systems and Societies (SL)

An Investigation into the Effects of Nitrogen and Phosphorus Fertilizer Concentrations on Aquatic Plant Growth and Water Quality

Environmental Issue

The overuse of nitrogen and phosphorus fertilizers and their role in eutrophication, hypoxia, and declining water quality.

Session: May 2025
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Identifying the Context

Environmental Issue

The overuse of nitrogen and phosphorus fertilizers and their role in eutrophication, hypoxia, and declining water quality.

Introduction

Fertilizers have been essential in supporting our growing global population, with estimates suggesting that just under half of our entire population is dependent on synthetic fertilizers (Ritchie et al.). These fertilizers, while beneficial for boosting agricultural yields, can unfortunately impact plant and animal life (including humans) negatively (Keena et al.). For instance, eutrophication is a complex process caused by excessive nutrient loading, primarily nitrogen and phosphorus, leading to overgrowth of algae and aquatic plants that deplete oxygen ("The Global Assessment of Private Sector Impacts on Water"). This contributes to hypoxic and anoxic "dead zones," resulting in aquatic organisms dying, reduced sunlight, declining water quality, contaminated water supplies, and ocean acidification (Chislock et al. 1). Locally, this issue affects water bodies near agricultural zones where fertilizer runoff is common, but it is also a global issue affecting large bodies of water like the Mississippi River, the Gulf of Mexico, Susquehanna River, and Chesapeake Bay (Chislock et al. 1).

This environmental issue is very relevant to the investigation as it concerns how varying concentrations of nitrogen and phosphorus impact aquatic environments. The relationship between fertilizer use and the degradation of water quality is rooted in the over-application of these nutrients to agricultural fields, which ultimately runoff into water sources. This is why the focus of the research is on *Cryptocoryne beckettii*, an aquatic plant, as it serves as a key indicator of how these nutrients affect plant growth and the dissolved oxygen levels in water. By investigating how different concentrations of nitrogen and phosphorus affect the growth of *Cryptocoryne beckettii*, this investigation aims to determine which fertilizer concentration has the most beneficial and detrimental effects and how nutrient imbalances impact water quality and oxygen levels within aquatic ecosystems.

Research Question

How will varying concentrations of nitrogen and phosphorus in fertilizers (%) affect aquatic plant growth (cm) and as a result dissolved oxygen concentration in the water (mg/L) after 7 days?

Connection Between the Environmental Issue and the Research Question

The overuse of nitrogen and phosphorus fertilizers is directly tied to the research question, which investigates how different concentrations of these nutrients impact the growth of *Cryptocoryne beckettii* and the dissolved oxygen concentration in water. This assessment seeks to explore the effects of varying fertilizer concentrations on both plant growth and oxygen levels over a 7-day period. By testing different fertilizer concentrations, the assessment will deeply explore how nutrient levels can create both positive and negative outcomes in aquatic environments and ecosystems.

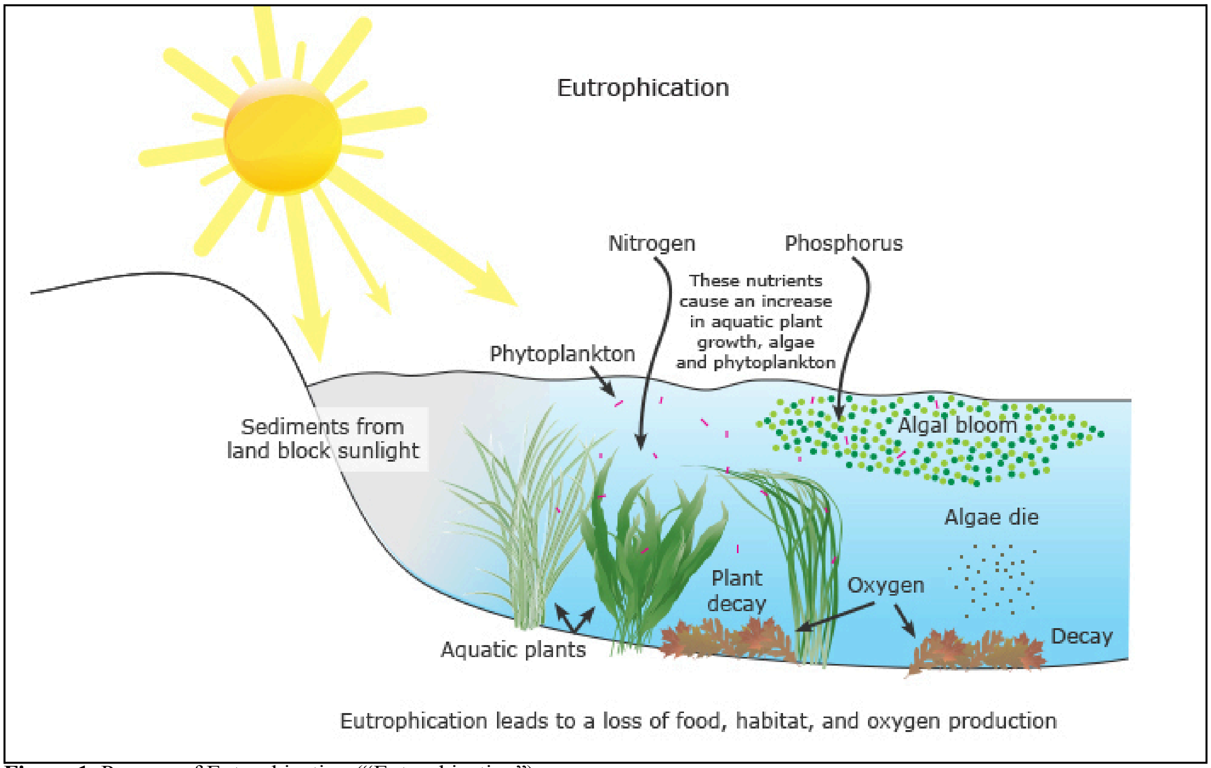


Figure 1. Process of Eutrophication ("Eutrophication").

Hypothesis

Four types of fertilizers will be tested in the experiment: one with high nitrogen and phosphorus, one with low concentrations, one with more phosphorus, and one with more nitrogen. It is hypothesized that high nitrogen and phosphorus will increase plant growth but decrease dissolved oxygen. Low concentrations will result in minimal plant growth and higher oxygen levels. Plants in the phosphorus-rich solution are expected to grow more than those in the nitrogen-rich solution, with lower oxygen levels resulting in the phosphorus jar. This prediction comes from the understanding that phosphorus tends to accumulate in water bodies more than nitrogen during eutrophication, contributing to oxygen depletion

(Smyth et al.). Ultimately, it is hypothesized that higher concentrations of phosphorus and nitrogen will result in enhanced plant growth, but simultaneously result in lower levels of dissolved oxygen.

Planning

Variables

- **Independent variable:** Fertilizer Concentrations of Nitrogen and Phosphorus

1. Fertilizer A: 30 mL (62% nitrogen and phosphorus)
2. Fertilizer B: 30 mL (1.5% nitrogen and phosphorus)
3. Fertilizer C: 30 mL (15% phosphorus, 10% nitrogen)
4. Fertilizer D: 30 mL (30% nitrogen, 10% phosphorus)

- **Dependent variable:** Growth of *Cryptocoryne beckettii* (cm) and dissolved oxygen (DO) levels, measured daily over 7 days.

- **Control Variables**

1. Control Jar: One jar will not contain any fertilizer, and growth will be measured weekly. It will be kept in the same environment as the other jars to establish a baseline for comparison.
2. Amount of Substrate: Each jar will contain 2 cups of fine pebble substrate to ensure consistent root depth for accurate measurements.
3. Light Source: An LED grow light will provide 12 hours of consistent daily light across all jars, preventing growth differences from varying light exposure.
4. Initial Size of Plants: All plants will start at 7 cm tall to maintain consistency in initial conditions.
5. Temperature: The experiment will take place at room temperature (22-24°C / 72-75°F) to control temperature variations.
6. Water: Each jar will receive 2.5 cups of filtered water to maintain consistency in water quality across all jars.

Justification for Sampling Strategy

The sampling strategy was chosen to assure accurate data and consistency across fertilizer treatments. The experiment uses five jars: four with different fertilizer concentrations (A, B, C, D) and one control jar with no fertilizer. This setup enables clear comparisons of the fertilizer effects on plant growth and dissolved oxygen levels. Growth will be measured daily, and oxygen levels monitored over a week to track trends. By controlling variables, the experiment should provide precise results. Data from all jars will help measure the influence of each fertilizer treatment on plant growth and oxygen levels.

Materials

- 5 *Cryptocoryne beckettii* (7 cm each)
- 4 types of fertilizers:
  - ➢ 30 mL of fertilizer with a high nitrogen and phosphorus content
  - ➢ 30 mL of fertilizer with a low nitrogen and phosphorus content
  - ➢ 30 mL of fertilizer with more phosphorus than nitrogen
  - ➢ 30 mL of fertilizer with more nitrogen than phosphorus
- 5 clear glass jars (600 mL)
- Pebble substrate (2 cups)
- Filtered water (2.5 cups)
- 1 ruler (30 cm)
- 1 thermometer (Fahrenheit or Celsius)
- 1 LED grow light
- 1 Digital Dissolved Oxygen Meter
- 3 coin batteries (1.5 volts)
- 1 timer/clock
- 1 notebook/digital device
- 1 pair of gloves
- 1 pair of goggles
- 1 tape dispenser and marker
- 1 plastic spoon
- 1 cellular device (to use the Vernier Graphical Analysis app)
- Measuring cups and spoons
- Cleaning materials (e.g., cloth, paper towels)

Risk Assessment and Ethical Considerations

Safety is essential in any experiment. In this case, wearing gloves and goggles while handling fertilizers helps prevent irritation. Fertilizer-related steps should be done outdoors to reduce inhalation risks, and manufacturer instructions must be followed carefully. Working in a well-ventilated area with a first-aid kit on hand would also be a safe decision. Ethically, the *Cryptocoryne beckettii* plants should be handled with care, and measures must be taken to protect local wildlife from potential fertilizer toxicity.

Securing the experimental area and disposing of excess fertilizer responsibly further assures safety. Therefore, adhering to these precautions allows the experiment to be conducted responsibly and without unnecessary risk.

Method

1. Gather materials such as the *Cryptocoryne beckettii* plants, fertilizers, jars, substrate, filtered water, measuring tools, tape, marker, and the dissolved oxygen meter.
2. Measure 2 cups of substrate for each of the 5 jars, inserting it accordingly.
3. Using tape and a marker, label each jar from A to E.
4. Measure each *Cryptocoryne beckettii* plant to ensure they have the same initial height, then place one plant in the substrate of each jar.
5. Add 2.5 cups of filtered water to each jar, ensuring the same water level.
6. Install batteries in the dissolved oxygen meter and measure the initial dissolved oxygen (DO). To do this, turn on the probe, submerge it in the water, connect to the Vernier Graphical Analysis app, and record the stabilized reading. Ensure measurements are taken at the same time each day for consistency.
7. Measure 30 mL of fertilizer for each jar:
    a. Jar A: Fertilizer with low nitrogen and phosphorus content.
    b. Jar B: Fertilizer with more phosphorus than nitrogen.
    c. Jar C: Fertilizer with more nitrogen than phosphorus.
    d. Jar D: Fertilizer with a high concentration of nitrogen and phosphorus.
    e. Jar E: No fertilizer (control).
8. Pour fertilizer into the respective jars and mix gently with a plastic spoon.
9. Position all jars under an LED grow light for 12 hours of light daily, using a timer to maintain consistency.
10. Everyday, measure plant height with a 30 cm ruler and record the growth in centimeters.
11. After 7 days, measure the final dissolved oxygen levels (see Step 6) and analyze the data to compare plant growth and dissolved oxygen levels across the different fertilizer concentrations.

Results, Analysis, and Conclusion

Raw Data

Table 1. Growth of *Cryptocoryne beckettii* in Each Jar.

Growth of *Cryptocoryne beckettii* in Each Jar (cm) Over the 7-Day Experiment										
Jars	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Mean**	**SD**	**Percentage Change (%)**
"A" - contains fertilizer with low concentrations of nitrogen and phosphorus.	7	7	7.2	7.3	7.4	7.3	7.5	7.24	0.190	3.43
"B" - contains fertilizer with more phosphorus than nitrogen content.	7	7.1	7.3	7.3	7.5	7.7	7.8	7.39	0.297	5.57
"C" - contains fertilizer with more nitrogen than phosphorus content.	7	7	7.3	7.4	7.6	7.5	7.7	7.36	0.276	5.14
"D" - contains fertilizer with high concentrations of nitrogen and phosphorus.	7	7.2	7.4	7.4	7.6	7.7	8.1	7.49	0.358	7
"E" - does not contain fertilizer.	7	7	7.1	7.2	7.2	7.5	7.5	7.21	0.212	3

Table 2. Dissolved Oxygen Concentration Before and After Experiment.

Dissolved Oxygen Concentration in Each Jar (mg/L) Before and After the Experiment was Conducted			
Jars	**Before the experiment**	**After the experiment**	**Percentage Change (%)**
"A" - contains fertilizer with low concentrations of nitrogen and phosphorus.	11.9	4.05	-66.0
"B" - contains fertilizer with more phosphorus than nitrogen content.	11.9	1.4	-88.2
"C" - contains fertilizer with more nitrogen than phosphorus content.	11.9	1	-91.6
"D" - contains fertilizer with high concentrations of nitrogen and phosphorus.	11.9	0.1	-99.2
"E" - does not contain fertilizer.	11.9	5.45	-54.2

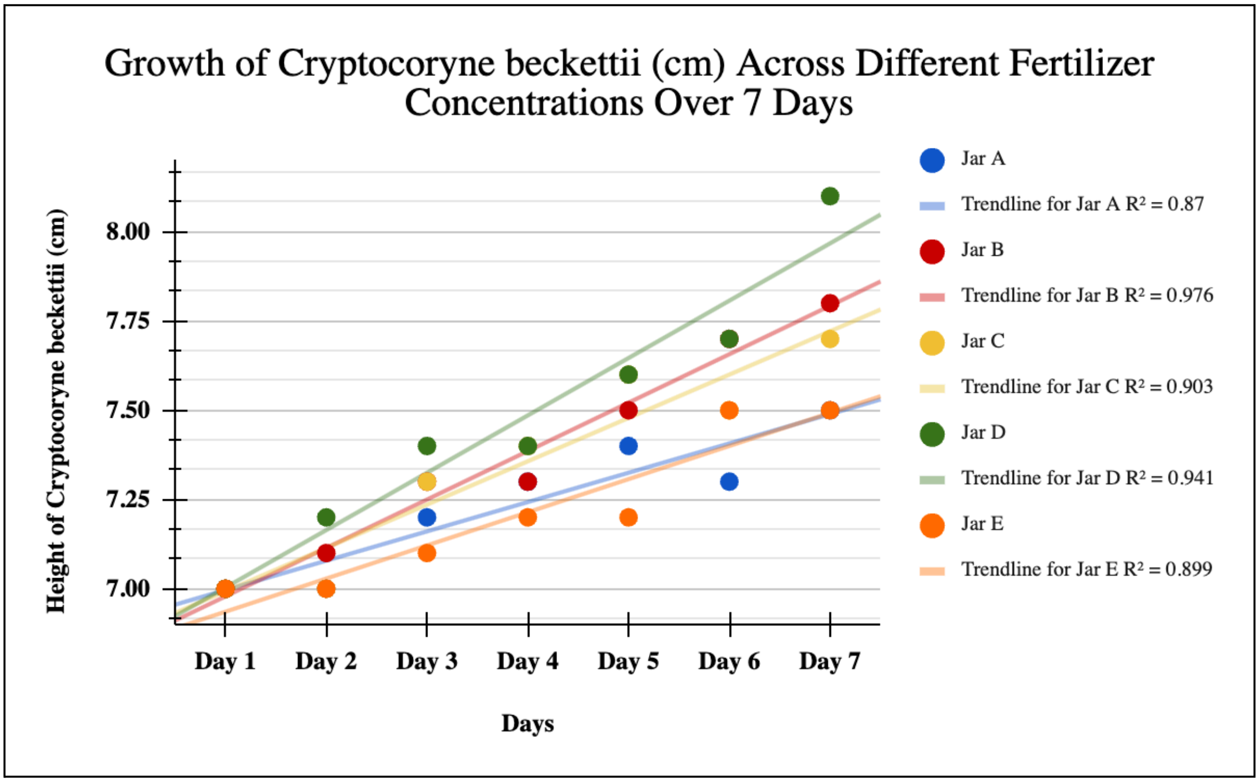
Qualitative Data

- **Jar A** showed steady, gradual growth, with no noticeable changes in water clarity.

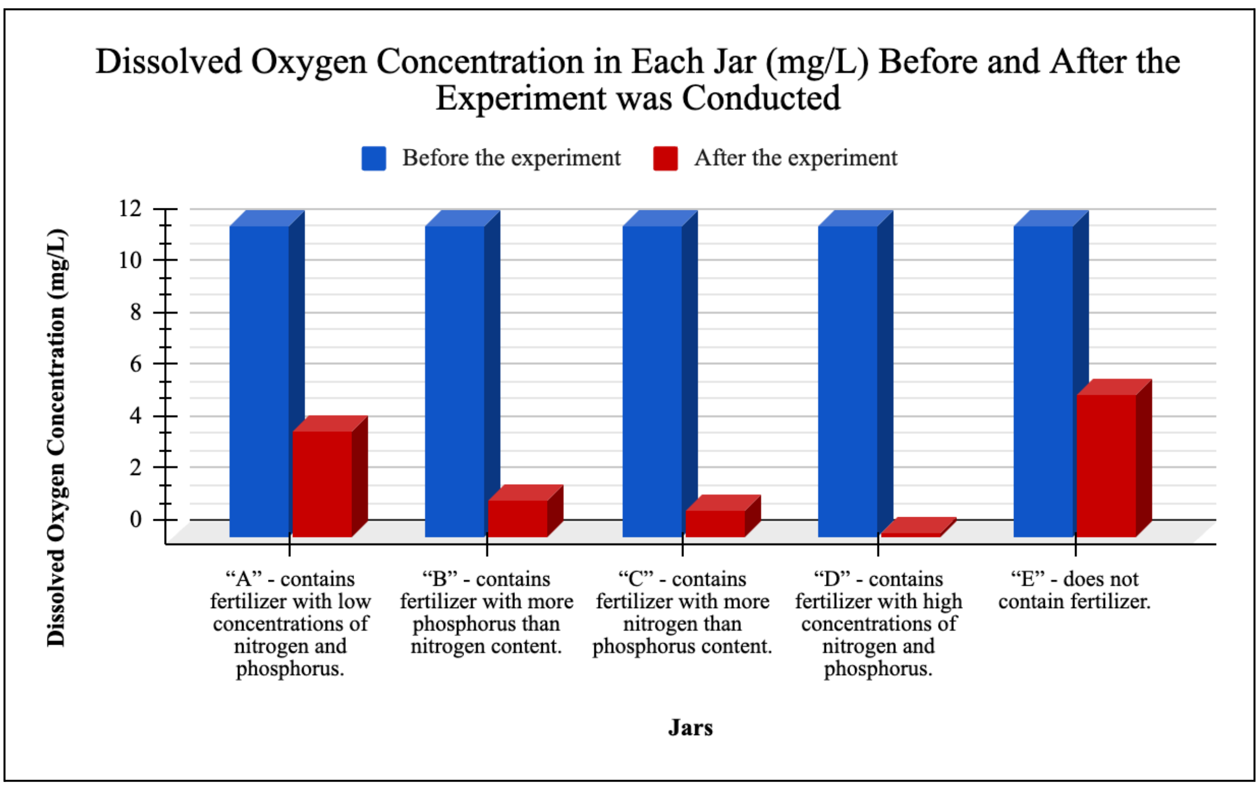
- **Jar B** grew faster than Jar A, with plants looking more vibrant and healthy, showing a positive response to the fertilizer.
- **Jar C** grew slower than the others but still had healthy plants and clear water.
- **Jar D** grew the quickest, with overgrown plants by day 7 and some turbidity in the water, indicating a strong fertilizer effect.
- **Jar E** had minimal growth, with stunted plants and no algae, showing little response to the fertilizer.

Figure 2. Experimental Setup on Day 1

Processed Data



Graph 1. *Cryptocoryne beckettii* Growth (cm) Across Fertilizer Concentrations Over 7 Days



Graph 2. Dissolved Oxygen (mg/L) in Jars Before and After Experiment

Sample Calculations

1. **Percentage Change**
   = ((Final Value−Initial Value) / Initial Value) × 100
   Example (Jar A Dissolved Oxygen Concentration)
   = ((4.05-11.9) / 11.9) x 100
   ≐ -66.0%
2. **Mean**
   = Sum of All Data Points / Number of Data Points
   Example (Growth in Jar A)
   = (7 + 7 + 7.2 + 7.3 + 7.4 + 7.3 + 7.5) / 7
   ≐ 7.24
3. **Standard Deviation (SD)**
   The standard deviation was calculated using the STDEV.S function on Google Sheets.
   Example (Growth in Jar A)
   =STDEV(D3:H3)

Interpretation of Data

The data from this investigation reveals a clear relationship between nutrient concentrations and both plant growth and dissolved oxygen levels in aquatic environments. Higher concentrations of nitrogen and phosphorus, particularly in Jar D, revealed the most growth of *Cryptocoryne beckettii*, with a 7% increase in plant height. Jars with moderate nutrient levels (B and C) also exhibited notable growth, which suggests that both nitrogen and phosphorus contribute to plant development. However, this increase in growth came at the cost of dissolved oxygen, which decreased significantly in jars with higher nutrient concentrations. Jar D showed the most extreme reduction in oxygen levels (99.2%), supporting the idea that excessive nutrients can lead to eutrophication, where algal blooms or microbial breakdown of organic matter deplete oxygen in the water. Additionally, Jar E, the control group with no fertilizer, maintained the least drop in oxygen levels and had minimal plant growth, indicating that without additional nutrients, plant growth is limited, but oxygen levels remain more stable. The strong correlations between nutrient concentrations and both plant growth (R^2 values of 0.941 for Jar D and 0.976 for Jar B) and oxygen reduction further demonstrates the need for careful nutrient management in aquatic systems to avoid detrimental ecological effects like oxygen depletion.

Discussion and Evaluation

Conclusion

Overall, the data from the investigation are closely linked to the environmental issue of eutrophication, which reveals the ongoing decline in water quality. These results reveal the urgency of addressing nutrient pollution to protect aquatic ecosystems and improve the health of water bodies. The experiment was able to demonstrate how increased nutrient levels can trigger excessive plant growth, which, while seemingly beneficial at first, ultimately contributes to a reduction in dissolved oxygen levels. This reflects real-world scenarios in which the agricultural runoff leads to algal blooms that deplete oxygen, resulting in hypoxic zones where aquatic life struggles to survive. Therefore, this investigation was able to demonstrate and explore the importance of regulating fertilizer use to prevent any unintended ecological harm.

Strengths, Weaknesses, and Limitations

One vital strength throughout the entire investigation was the controlled nature of the experiment. Variables such as light exposure, water volume, and plant starting height were carefully standardized to ensure that the observations were solely because of fertilizer concentration. Additionally, the use of the digital dissolved oxygen meter allowed for precise and consistent measurements throughout the experiment.

However, there were some limitations. For instance, the experiment was conducted over just seven days, which may not have completely captured the long-term effects of nutrient accumulation and oxygen depletion. Additionally, the experiment was performed in only a jar, which does not account for external factors such as water circulation, microbial activity, or interactions with other aquatic organisms that naturally occur in real water bodies. Another limitation was the lack of more trials and jars, which restricted the ability to identify possible anomalies in the data.

To improve the dependability of the results, future studies should extend the experiment duration to observe long-term effects. Adding more trials for each fertilizer concentration would also improve reliability. Incorporating a more dynamic system with aeration or flowing water could also help better reflect real aquatic environments. Finally, measuring other water quality factors, such as pH, temperature, and nitrate levels, would also allow for a better understanding of how fertilizers impact all aspects of aquatic ecosystems.

Further Areas of Research

Future research could explore the effects of different types of fertilizers, such as organic versus synthetic fertilizers, to determine if they have different impacts on plant growth and water quality. Additionally, investigating the role of microbial activity in breaking down excess nutrients and reducing eutrophication could be a very interesting area for further study. Lastly, studying the impact of fertilizers on more aquatic species, like algae and fish, could also provide a more well-rounded understanding of ecosystem health and fertilizer impact.

Applications

One possible solution to reduce the issue of eutrophication is the implementation of buffer zones along agricultural fields. Wetland buffer zones capture and recycle part of nutrient-rich runoff water before it reaches rivers and lakes, thereby reducing nutrient loads in surface waters at the land-water interface (Walton et al. 1). Therefore, based on the results of this investigation, this solution could significantly reduce the direct input of nitrogen and phosphorus into aquatic environments and limit excessive plant growth and dissolved oxygen depletion.

Evaluation of the Solution

The strength of this solution lies in its practicality and cost-effectiveness. Buffer zones are relatively easy to implement and require minimal maintenance compared to more technologically intensive solutions such as chemical water treatments. Natural buffers (i.e. local vegetation) also help prevent soil erosion and sedimentation and help to protect natural swales (a shady spot, or a sunken or marshy place) (Palaskey).

However, buffer zones have some limitations. For instance, they are not a complete solution, as some nutrients can still leach into water bodies, especially during heavy rainfall. Additionally, they require land, which may not always be available or feasible for farmers to simply set aside. Therefore, to maximize effectiveness, buffer zones should be implemented alongside other strategies, such as precise fertilizer application, reduced fertilizer use, and improved wastewater management.

Ultimately, this investigation highlights the major impact of nitrogen and phosphorus fertilizers on aquatic plant growth and dissolved oxygen levels. While fertilizers enhance growth, they also contribute to oxygen depletion which shows the immense real-world consequences of eutrophication. Future research and practical solutions, such as buffer zones, would help in significantly reducing these effects and will help encourage and promote sustainable agricultural practices that help protect not only our environment, but also the environment for generations to come.

Works Cited

Chislock, M. F., et al. "Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems | Learn Science at Scitable." *Nature Education Knowledge*, vol. 4, no. 4, 2013, p. 10. *Nature*, https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/. Accessed 8 Feburary 2025.

"Eutrophication." *Science Learning Hub*, 2013, https://www.sciencelearn.org.nz/images/1023-eutrophication. Accessed 8 February 2025.

"The Global Assessment of Private Sector Impacts on Water." *Global Institute for Water Security*, https://water.usask.ca/valuing-water-global-assessment/report/chapter-3.php. Accessed 8 February 2025.

Keena, Mary, et al. "Environmental Implications of Excess Fertilizer and Manure on Water Quality." *North Dakota State University*, August 2022, https://www.ndsu.edu/agriculture/extension/publications/environmental-implications-excess-fertilizer-and-manure-water-quality. Accessed 8 February 2025.

Palaskey, Madison. "Buffer Zones." *ArcGIS StoryMaps*, 28 April 2022, https://storymaps.arcgis.com/stories/88ffd9f6dcad480c88b71ff7d5216507. Accessed 11 February 2025.

Ritchie, Hannah, et al. "Fertilizers." *Our World in Data*, https://ourworldindata.org/fertilizers. Accessed 28 October 2024.

Smyth, Ashley, et al. "(PDF) Rethinking the Role of Nitrogen and Phosphorus in the Eutrophication of Aquatic Ecosystems." *ResearchGate*, 8 January 2022, https://www.researchgate.net/publication/357677893_Rethinking_the_Role_of_Nitrogen_and_Phosphorus_in_the_Eutrophication_of_Aquatic_Ecosystems. Accessed 28 October 2024.

Walton, Craig R., et al. "Wetland buffer zones for nitrogen and phosphorus retention: Impacts of soil type, hydrology and vegetation." *Science of The Total Environment*, vol. 277, 2020. *ScienceDirect*, https://www.sciencedirect.com/science/article/abs/pii/S0048969720322269. Accessed 11 February 2025.