Phytoremediation rates of morning glory (*Ipomea asarifolia*) in an aquaculture effluent hydroponic system

E A Kiridi 1 and A O Ogunlela 2

1 Department of Agricultural and Environmental Engineering, Niger Delta University, Bayelsa, Nigeria
2 Department of Agricultural and Biosystems Engineering, University of Ilorin, Kwara State, Nigeria

Email: kiriebi@yahoo.com

Abstract. Most fish farmers dispose of aquaculture effluent indiscriminately and this adversely affect the environment. On the other hand, conventional wastewater treatment plants are costly to install and run. This research studies morning glory phytoremediation in a hydroponic aquaculture effluent for possible use as a cheaper alternative to wastewater treatment. Four replicates containing about 100 g of morning glory in each hydroponic unit were studied at 7 days interval. Measured pre and post treatment parameters include: pH, electrical conductivity (EC), complete suspended solids (TSS) and total dissolved solids (TDS). Ammonium-nitrogen ($\text{NH}_4^+$-N), nitrite-nitrogen ($\text{NO}_2^-$-N), nitrate-nitrogen ($\text{NO}_3^-$-N), phosphorus ($\text{PO}_4^{3-}$-P) and biomass were also evaluated. Results showed that the percentage reduction in pH ranged from 1.9% to 11.6%, EC from 49.8% to 92.4%, TSS from 34.0% to 73.3%, TDS from 50.4% to 94.3%, $\text{NH}_4^+$-N from 38.9% to 85.2%, $\text{NO}_2^-$-N from 0% to 76.6%, $\text{NO}_3^-$-N from 63.2% to 90.4% and $\text{PO}_4^{3-}$-P from 10.0% to 52.5%. The recorded biomass was 417.0 g, 567.0 g, 642.0 g, 679.5 g. A paired sample t-test demonstrates that at a confidence level of 95 percent it can be statistically concluded that there was significant inequality between pre-and post-treatment values. This implies potency of this plant and can be useful in the treatment of aquaculture effluent.

1. Introduction

In Nigeria, commercial aquaculture is performed more in semi-closed concrete or plastic tanks and earthen ponds particularly in regions where there is no limit to freshwater supply. Dissolved oxygen is restricted in these structures and thus increases the accumulation of nitrite. As a consequence of nitrification, the quantity of dissolved oxygen decreases and the fish’s behavioral and physiological reactions change. They become less active and may stop feeding in others to preserve power and their remaining natural oxygen, and if dissolved levels of oxygen continue to decrease, the fish may die [1]. Effluents from such structures are generally dumped into the open or dug-out pits, thus contaminating the surface and groundwater [2]. Aquaculture effluent remediation is essential because water is a restricted resource in many fields and depending on the receiving water body, the complete mass loading of nutrients from effluents can lead to significant environmental degradation [3], [4]. Morning Glory (*Ipomea asarifolia*) is a perennial long-trailing herbaceous and sometimes twining weed usually seen in
freshwater rivers, sandy fields and dumps of waste. In nutrient-rich waters, it is also discovered to grow very well and can infest agricultural regions. This plant has certain phytochemical and antibacterial characteristics and is thus used for medicinal reasons [5]. Some researchers have successfully used aquatic macrophytes for effluent treatment [6], [7], [8], [9].

Local fish farmers indiscriminate disposal of aquaculture effluent is capable of raising ammonia, nitrites, nitrates and other contaminants in surface and groundwater above the permitted level. Also, the ineffectiveness of the appropriate regulatory organizations adds to the failure to comply with the authorized wastewater disposal standards and, as a consequence, the accompanying impact could result in an outbreak [2].

The objectives of this research were to measure both the pollutant concentration level of an aquaculture effluent at an adult stage of catfish production and the effects of Morning Glory’s (Ipomea Asarifolia) on the effluent at specific retention time so as to determine the suitability of possible reuse of the treated effluent.

2. Materials and Methods

2.1. Experimental site

The experimental site was an open space in front of the laboratory of the Department of Agricultural and Environmental Engineering, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria. Located in the vegetative mangrove swamp area, the University has a tropical climate with two seasons: the wet season from March to October and the dry season from November to April.

2.1.1 Experimental Procedure. The experiment was conducted as described by Kiridi and Ogunlela [9]. Appropriate quantities of Morning Glory (Ipomea Asarifolia) in their natural habitats were carefully harvested from within and around Yenagoa metropolis in Bayelsa State. They were then put in four replicates of hydroponic non-flow units containing the aquaculture effluent and a control. The aquaculture effluent was obtained from the Niger Delta University Fish Farm at the adult stage of fish production and the chemical analysis of the effluent are presented in Table 1. All gathered samples were kept in the refrigerator and subsequently sent to Niger Delta University’s Chemical Science Laboratory, Wilberforce Island, Bayelsa State, Nigeria to determine pH, electrical conductivity (EC), total suspended solids (TSS) and total dissolved solids (TDS). Ammonium-nitrogen ($\text{NH}_4^+$-N), nitrite-nitrogen ($\text{NO}_2^-$-N), nitrate-nitrogen ($\text{NO}_3^-$-N), phosphate ($\text{PO}_4^{3-}$-P) and plant biomass increase were also evaluated.

### Table 1. Chemical constituents of the aquaculture wastewater.

| Parameters (mg/l)       | Value |
|-------------------------|-------|
| pH                      | 6.4   |
| Electrical Conductivity, EC ($\mu$s cm$^{-1}$)$^a$ | 4020  |
| Total Dissolved Solids (TDS) | 2010  |
| Total Suspended Solids (TSS) | 12.60 |
| Ammonium-Nitrogen ($\text{NH}_4^+$-N) | 0.054 |
| Nitrite-Nitrogen ($\text{NO}_2^-$-N) | 0.338 |
| Nitrate-Nitrogen ($\text{NO}_3^-$-N) | 0.56  |
| Orthophosphate ($\text{PO}_4^{3-}$-P) | 0.40  |

$^a$Concentrations are not in mg/l

3. Results and Discussions

Initially, the morning glory appeared stressed in all the hydroponic units but grew quickly as the days of phytoremediation increased. Table 2 demonstrates that the morning glory was able to decrease the
concentration of nutrients of most of the chosen parameter within the first seven days following the negligible nutrient decrease.

**Table 2.** Mean effects of the morning glory on some physicochemical characteristics of the aquaculture effluent and its weight for the 7 days intervals.

| Effluent Parameter (mg l⁻¹) | Phytoremediation Period (Days) | 0 | 7 | 14 | 21 | 28 |
|-----------------------------|--------------------------------|---|---|---|----|----|
| pH                          |                                | 6.40 | 6.11 | 5.68 | 6.19 | 5.66 |
| EC (µs cm⁻¹)                |                                | 4020.0 | 1957.3 | 625.0 | 304.5 | 229.8 |
| TDS                         |                                | 2010.0 | 978.8 | 312.8 | 152.3 | 114.8 |
| TSS                         |                                | 12.60 | 4.74 | 3.36 | 4.31 | 7.42 |
| NH₄⁺-N                     |                                | 0.054 | 0.035 | 0.013 | 0.008 | 0.013 |
| NO₂⁻-N                     |                                | 0.338 | 0.206 | 0.123 | 0.079 | 0.087 |
| NO₃⁻-N                     |                                | 0.560 | 0.120 | 0.091 | 0.054 | 0.070 |
| PO₄³⁻-P                    |                                | 0.40 | 0.53 | 0.35 | 0.20 | 0.19 |
| Weight (g)                  |                                | 100.8 | 417.0 | 567.0 | 642.0 | 679.5 |

Table 3 indicates an effluent pH of 6.4 and a percentage decrease ranged from 1.9% to 11.6% making the effluent mildly acidic. This outcome implies that the treated effluent may adversely affect the development of fish. For fish manufacturing, [10] suggested that the pH range be 6.5-8.0. In bottom sediments, the decay of matter and oxidation of compounds also change the pH of water bodies. Slow or poor development will lead in water with a pH of 4.0-6.0 or 9.0-10.0 and water management for increasing acidity in fish farming, is liming. The EC effluent was 4020 and the morning glory therapy resulted in a decrease ranging from 49.8% to 92.4% (Table 3). EC may be used to acquire salinity or TDS estimates [10].

**Table 3.** Nutrient reduction by morning glory on pH and EC of the aquaculture effluent for the time interval.

| Parameter | Phytoremediation Intervals (days) | Treatment | Influent | Effluent | Difference | Reduction (%) |
|-----------|-----------------------------------|-----------|----------|----------|------------|--------------|
| pH        | 7                                 | Control   | 6.40     | 6.52     | -0.12      | -1.9         |
|           | 14                                | Morning Glory | 6.40    | 6.11     | 0.29       | 4.5          |
|           |                                   | Control   | 6.40     | 6.68     | -0.28      | -4.4         |
The mean TDS and TSS concentration were 2010 and 12.6 respectively (Table 4). The decrease in TDS concentration varies from 50.4% to 94.3%, while for TSS it ranges from 34.0% to 73.3%. The elevated TDS concentration may have been caused by uneaten fish feed and fish faeces. Ammonia-nitrogen (NH$_4^+$ -N), a by-product of catabolism of fish protein, is excreted as unionized ammonia (NH$_3$), which is highly toxic to aquatic animals [10]. Results show that the reduction of NH$_4^+$ -N from the hydroponic units containing morning glory ranged from 38.9 to 85.2% (Table 4). Nitrite-nitrogen (NO$_2^-$ -N) and nitrate-nitrogen (NO$_3^-$ -N) concentrations were respectively 0.338 mg / l and 0.56 mg / l. Table 5 displays that the NO$_2^-$ -N decrease ranged from 0 to 76.6%, while the NO$_3^-$ -N decrease ranged from 63.2 to 90.4% (Table 6) The orthophosphate (PO$_4^{3-}$ -P) aquaculture effluent was 0.4 mg / l. Results indicate that the PO$_4^{3-}$ -P decrease ranged from 10.0 to 52.5 percent.

A paired test t-test using Microsoft Excel Stat software evaluated the impact of the morning glory therapy. Table 7 shows that at a confidence level of 95 percent, the analysis showed that t (critical) is less than t (Stat) and p<0.05 except for PO$_4^{3-}$ -P, so it can be statistically concluded that there is significant inequality between pre-treatment and post-treatment values. This indicates the efficacy of morning glory in remediation of aquaculture effluent.
Table 4. Pollutant reduction by morning glory on TDS and TSS of the aquaculture effluent for the time interval.

| Parameter | Phytoremediation Intervals (days) | Treatment          | Influent (mg/l) | Effluent (mg/l) | Reduction Difference (%) |
|-----------|----------------------------------|--------------------|-----------------|-----------------|--------------------------|
| TDS       | 7                                | Control            | 2010.0          | 1008.5          | 1001.5                   | 49.8                     |
|           |                                  | Morning Glory      | 2010.0          | 978.8           | 1031.2                   | 51.3                     |
|           | 14                               | Control            | 2010.0          | 636.8           | 1373.2                   | 68.3                     |
|           |                                  | Morning Glory      | 2010.0          | 312.8           | 1697.2                   | 84.4                     |
|           | 21                               | Control            | 2010.0          | 611.3           | 1398.7                   | 69.6                     |
|           |                                  | Morning Glory      | 2010.0          | 152.3           | 1857.7                   | 92.4                     |
|           | 28                               | Control            | 2010.0          | 691.8           | 1318.2                   | 65.6                     |
|           |                                  | Morning Glory      | 2010.0          | 114.8           | 1895.2                   | 94.3                     |
| TSS       | 7                                | Control            | 12.60           | 6.50            | 6.10                     | 48.4                     |
|           |                                  | Morning Glory      | 12.60           | 4.74            | 7.86                     | 62.4                     |
|           | 14                               | Control            | 12.60           | 8.32            | 4.28                     | 34.0                     |
|           |                                  | Morning Glory      | 12.60           | 3.36            | 9.24                     | 73.3                     |
|           | 21                               | Control            | 12.60           | 6.66            | 5.94                     | 47.1                     |
|           |                                  | Morning Glory      | 12.60           | 4.31            | 8.29                     | 65.8                     |
|           | 28                               | Control            | 12.60           | 3.64            | 8.96                     | 71.1                     |
|           |                                  | Morning Glory      | 12.60           | 7.42            | 5.18                     | 41.1                     |
Table 5. Pollutant reduction by morning glory on NH$_4^+$ -N and NO$_2^-$ -N of the aquaculture effluent for the time interval.

| Parameter   | Phytoremediation Intervals (days) | Treatment         | Influent (mg/l) | Effluent (mg/l) | Reduction Difference (%) |
|-------------|-----------------------------------|-------------------|-----------------|-----------------|--------------------------|
|              |                                   |                   |                 |                 |                          |
| NH$_4^+$ -N | 7                                 | Control           | 0.054           | 0.033           | 0.021                    | 38.9                     |
|              |                                   | Morning Glory     | 0.054           | 0.035           | 0.019                    | 35.2                     |
|              | 14                                | Control           | 0.054           | 0.018           | 0.036                    | 66.7                     |
|              |                                   | Morning Glory     | 0.054           | 0.013           | 0.041                    | 75.9                     |
|              | 21                                | Control           | 0.054           | 0.020           | 0.034                    | 63.0                     |
|              |                                   | Morning Glory     | 0.054           | 0.008           | 0.046                    | 85.2                     |
|              | 28                                | Control           | 0.054           | 0.028           | 0.026                    | 48.1                     |
|              |                                   | Morning Glory     | 0.054           | 0.013           | 0.041                    | 75.9                     |
| NO$_2^-$ -N | 7                                 | Control           | 0.338           | 0.338           | 0                       | 0                        |
|              |                                   | Morning Glory     | 0.338           | 0.206           | 0.132                    | 39.1                     |
|              | 14                                | Control           | 0.338           | 0.223           | 0.115                    | 34                       |
|              |                                   | Morning Glory     | 0.338           | 0.123           | 0.215                    | 63.6                     |
|              | 21                                | Control           | 0.338           | 0.143           | 0.195                    | 57.7                     |
|              |                                   | Morning Glory     | 0.338           | 0.079           | 0.259                    | 76.6                     |
|              | 28                                | Control           | 0.338           | 0.175           | 0.163                    | 48.2                     |
|              |                                   | Morning Glory     | 0.338           | 0.087           | 0.251                    | 74.3                     |
Table 6. Pollutant reduction by morning glory on NO$_3^-$-N and PO$_4^{3-}$-P of the aquaculture effluent for the time interval.

| Parameter | Phytoremediation Intervals (days) | Treatment | Influent (mg/l) | Effluent (mg/l) | Reduction Difference (%) |
|-----------|-----------------------------------|-----------|-----------------|-----------------|--------------------------|
| NO$_3^-$-N | 7                                 | Control   | 0.56            | 0.206           | 0.354 63.2              |
|           |                                   | Morning Glory | 0.56            | 0.120           | 0.440 78.6              |
|           | 14                                | Control   | 0.56            | 0.138           | 0.422 75.4              |
|           |                                   | Morning Glory | 0.56            | 0.091           | 0.469 83.8              |
|           | 21                                | Control   | 0.56            | 0.132           | 0.428 76.4              |
|           |                                   | Morning Glory | 0.56            | 0.054           | 0.506 90.4              |
|           | 28                                | Control   | 0.56            | 0.154           | 0.406 72.5              |
|           |                                   | Morning Glory | 0.56            | 0.070           | 0.490 87.5              |
| PO$_4^{3-}$-P | 7                                | Control   | 0.400           | 0.36            | 0.04 10                 |
|           |                                   | Morning Glory | 0.400           | 0.53            | -0.130 -32.5            |
|           | 14                                | Control   | 0.400           | 0.23            | 0.17 42.5               |
|           |                                   | Morning Glory | 0.400           | 0.35            | 0.050 12.5              |
|           | 21                                | Control   | 0.400           | 0.19            | 0.21 52.5               |
|           |                                   | Morning Glory | 0.400           | 0.200           | 0.200 50.0              |
|           | 28                                | Control   | 0.400           | 0.22            | 0.18 45                 |
|           |                                   | Morning Glory | 0.400           | 0.190           | 0.210 52.5              |
Table 7. Summary of paired sample t-test between pre-treatment and post treatment levels for pollutant level reductions in aquaculture effluent using morning glory.

| Effluent Parameter (mg l^{-1}) | Mean variable 1 | Mean variable 2 | Observations | df  | t (Stat) | t (Crit) | P value | Remarks |
|-------------------------------|----------------|----------------|--------------|-----|----------|----------|---------|---------|
| pH^a                          | 6.40           | 6.01           | 9            | 8   | 4.54     | 2.31     | 0.0010  | S       |
| EC(μs cm^{-1})^a              | 4020           | 1352.66        | 9            | 8   | 5.73     | 2.31     | 0.0004  | S       |
| TDS                           | 1020           | 676.92         | 9            | 8   | 5.73     | 2.31     | 0.0004  | S       |
| TSS                           | 12.60          | 6.13           | 9            | 8   | 6.30     | 3.31     | 0.0002  | S       |
| NH_4^+ -N                     | 0.054          | 0.022          | 9            | 8   | 5.12     | 2.31     | 0.0009  | S       |
| NO_2^- -N                     | 0.338          | 0.161          | 9            | 8   | 5.60     | 2.31     | 0.0005  | S       |
| NO_3^- -N                     | 0.56           | 0.17           | 9            | 8   | 6.66     | 2.31     | 0.0002  | S       |
| PO_4^{3-} -P                  | 0.40           | 0.33           | 9            | 8   | 1.54     | 3.31     | 0.1621  | NS      |

^a Concentrations are not in mg/l

*Treatment Remarks: S = Significant; NS = Not significant

4. Conclusions and Recommendations
The conclusion of this investigation is:

i. Morning glory was able to reduce the pollutant load in the aquaculture effluent to permissible limits
ii. Reduction in the pollutant loads increased with increase in the phytoremediation interval
iii. The treated effluent is safe for re-use
iv. Water resources can be conserved in places where it is limited with phytoremediation.
This study has shown that a feasible alternative to conventional treatment technique is phytoremediation. It is cheaper and should therefore be embraced in the design and operation of effluent treatment for aquaculture by wastewater managers. The effects of aquatic macrophytes on other effluents should also be investigated.

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