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ENVIRONMENTAL MANAGEMENT FOR SUSTAINABLE GROWTH OF AQUACULTURE INDUSTRY

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***Abstract*— In the present study, Shrimp ponds are considered at Koduru village, near Gudivada, Krishna District. In the study areas Litopenaeus Vannamei Shrimp is being cultured. The water quality in the ponds were analysed during the culture period when water exchange is conducted every 15 days. During harvest time, entire pond is drained off and the water quality is also monitored during the harvest. The quantity of effluent generated during the harvest time is 1,31,625 m^3. Every fortnight water samples were collected at pond outlets and monitored the water quality parameters such as pH, DO, TSS, TDS, BOD, COD, Ammonia, Nitrites, Nitrates, Phosphates. The values are compared with the standard guidelines prescribed by the Coastal Aquaculture Authority (CAA).**

The project mainly focuses on the treatment of effluent by using Phytoremediation technique which is first of the kind to use aqua effluents for Phytoremediation practice. The variety of plants like Eichhornia Crassipes, Pistia Stratiotes, were used for demo and pilot scale experimentation purpose. The effluent or wastewater during harvest period is collected, a small quantity of wastewater or effluent is taken into a small container or tub an aquatic plants or species were introduced. The water quality in the tub was monitored initially, after 7 days, 15 days, 21days, 30 days for the parameters pH, DO, TSS, TDS, BOD, COD, Ammonia, Nitrites, Nitrates, Phosphates and the results were tabulated. By using Pistia Stratiotes higher removal efficiencies of 91.54% for TSS, 64.01% for TDS, 93.3% for BOD, 94.68% for Ammonia, 78.9% for Nitrites, 82.9 % for Nitrates was achieved. The COD removal efficiency of 83.33% was achieved by using Eichhornia Crassipes where as 78.47% efficiency was achieved by using Pistia Stratiotes. The phosphates removal efficiency was 98.11% by using Pistia Stratiotes. The biomass gain for Pistia Stratiotes was 982 grams/m^2 whereas by using Eichhornia Crassipes was only 933 grams/m^2. The biomass produced can be harvested periodically, which can be used in generation of biofuel, which is an environmentally friendly technology.

Finally, the pilot scale experimentation is successful and achieved satisfactory performance along with growth of biomass.

***Keywords*— Phytoremediation, Litopenaeus Vannamei, Coastal Aquaculture Authority, Mangroves, Salt marshes**

I. INTRODUCTION

A. Background

Aquaculture which is also known as aqua farming is defined as cultivating of the aquatic species such as fish, crustaceans, molluscs, aquatic plants, algae in freshwater and saltwater under controlled conditions. The worldwide aquaculture production has been increased from 2 million tons in 1950 to 50 million tons at present. In India the aquaculture production has been increased from 17,910 tons in 1950 to 61,82,000 tons in 2017 which shows immense increase. The main cause for this huge increase in aquatic species production is blue revolution. In India blue revolution was introduced during seventh five-year plan (1985- 1990) by central government for development of aquaculture. In the aquaculture production India is the second largest country in the world. Fisheries and Aquaculture acts as an important sector in food production and is playing an important role in meeting the global food demand. Globally, the demand for the protein food is increasing, leading to the aquatic species are being cultured in the captive environment as their body is made up of high protein content. This is leading the aquacuturists to follow more intensive methods for grow aquatic species. Due to the adoption of more and more intensive methods the discharge waters from the aquaculture farms are containing high organic content (mainly resulting from uneaten feed and faecal matter), dissolved metabolites and last but not the least, various forms of chemicals (fertilizers and heavy metals) having negative impacts on the environment. The main consequences of intensive aquafarming is destruction of mangroves, salt marshes, agricultural lands for pond preparation; depletion of ground water levels, ground water salinization, organic matter enrichment and nutrient enrichment.

B. Study Area

The study area is considered is at Koduru village, Mudinepalli Mandal, near Gudivada, Krishna district. Litopenaeus Vannamei variety of Shrimp is being cultured in the ponds taken for experimental purpose.

C. Objectives

1. To monitor discharge raw water quality in aquaculture ponds during culture period and harvest.
2. To estimate the generation of wastewater quantity.
3. To propose methods to improve water quality of discharge water from aquaculture ponds.

4. To analyse efficiency of various aquatic plants in improving quality of wastewater.
5. To design effluent treatment system to existing farm.

II. Materials and Methods

A. Introduction

In the present study, every fortnight wastewater samples were collected during the culture period and during harvest, when water exchange is carried out, near the farm outlet. Laboratory analysis was carried out for all the samples collected and the results were recorded. The parameters analysed were pH, DO, TSS, TDS, BOD, COD, Ammonia, Nitrites, Nitrates, Phosphates. This chapter presents the characterization of wastewater from the farms during the entire culture period and harvest. Then, the materials, experimental setup, procedures and methods used to treat the wastewater are presented.

B. Effluent discharge standards from aquaculture farms

Coastal Aquaculture Authority (CAA) provides guidelines and standards to aquaculture farms for wastewater discharges from farms. These guidelines mandates that the discharge waters should be within the permissible limits as stated below in Table I.

TABLE I
DISCHARGE STANDARDS PRESCRIBED BY CAA FOR AQUAFARMS

S.No.	Parameter	Discharge point into Creek/Estuaries-When same inland water courses are used as water source and disposal point
1	pH	6-8.5
2	D.O(ppm)	>3
3	Total Suspended Solids (ppm)	100
4	Total Dissolved Solids (ppm)	-
5	Biochemical Oxygen Demand (ppm)	20
6	Chemical Oxygen Demand (ppm)	75
7	Ammonia (ppm)	0.5
8	Nitrites (ppm)	-
9	Nitrates (ppm)	-
10	Total Nitrogen as N (ppm)	2
11	Phosphates (ppm)	0.2

C. Discharge water analysis from Aquaculture Ponds

The effluents were collected from the pond outlets. Water analysis of pond discharge is shown in Table II. Graphs were also plotted to show the variation as shown in Fig. 1. Ponds discharges are collected once in fortnight during the growth period which is calculated as Day of Culture (DOC). The water during the harvest is also analysed and Phytoremediation technique is applied to treat the effluents so that the water is achieved permissible limits stipulated by Coastal Aquaculture Authority (CAA).

TABLE II
VARIATION IN WATER QUALITY DURING CULTURE PERIOD AND HARVEST

S.No.	Parameter	DOC 0	DOC 15	DOC 30	DOC 45	DOC 60	DOC 75	DOC 90	DOC 109 (Harvest)
1	pH	7.4	8.07	8.33	8.57	7.97	8.12	8.26	6.75
2	DO (ppm)	5.4	4.9	4.2	4.6	4.4	4.1	4.3	1.6
3	TSS (ppm)	98	213	402	586	737	872	925	1478
4	TDS (ppm)	620	678	858	1106	1284	1380	1462	2034
5	BOD (ppm)	-	3	10	19	23	39	55	224
6	COD (ppm)	-	4	17	28	46	58	86	288
7	Ammonia (ppm)	-	0.04	0.15	0.33	0.39	0.55	0.96	8.47
8	Nitrite(ppm)	-	-	-	0.03	0.05	0.06	0.18	2.42
9	Nitrate(ppm)	-	-	-	-	0.03	0.09	0.27	3.68
10	Phosphates(ppm)	-	0.2	1.1	1.8	3.2	4.4	6.8	10.6

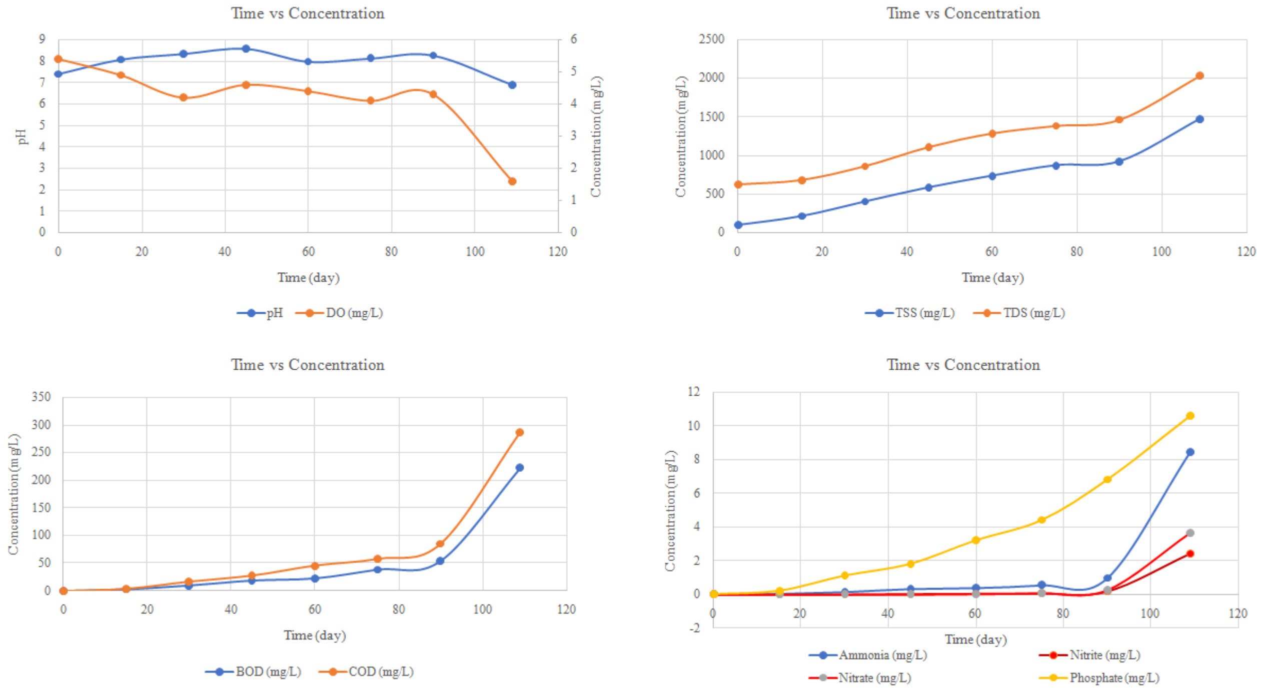

Fig. 1 Graphs showing variation in water quality during culture period and harvest

D. Phytoremediation

The term Phyto in ancient Greek literally means plant and Remedium in Latin means restoring balance. To address the problems of environmental management and sustainable development, a new branch of Civil Engineering called as Bioengineering is developed which integrates live materials mainly plants and microorganisms. It is green, cheaper alternative compared to hard, costly civil engineering works for reconstructing the environment. The phytoremediation technique was used for the first time in improving water quality during 1960s and 1970s. Based on location of the contaminated sites like air, water, or land; the plants which can grow in the respective habitats are chosen. In dealing with treating wastewater, aquatic plants or algae are chosen. The aquatic plants are again classified into submergent, emergent and floating plants.

In the present study, floating aquatic plants have been used. The role of phytoremediation by plants in reducing the contaminants is because of the effective root system of plants. The root system absorbs the contaminants and heavy metals form the wastewater during their metabolism process. Plants solely are responsible for remediation by using its own natural process to clean wastewater and does not require any external agency. The pollution remains localized and confined to a particular area as the plants not only decontaminates pollutants but also inhibits the spreading of pollutant from one site to another. After the aquatic plants grow, they are harvested. The harvested plants will have secondary uses. They can be used in generation of biofuel or fodder for food to animals. While using as fodder care must be taken for contaminants present in the plant biomass. If there are any toxic contaminants it should not be used as fodder because toxic contaminants may harm the animals eating them.

E. Mechanisms of Phytoremediation

1. *Phyto-Stabilization:* In the process of Phyto-Stabilization the chemical substances produced by the roots immobilizes the pollutants rather than degrading the pollutants. The main aim of this process is long term stabilization and containment of the pollutant.
2. *Phyto-Accumulation:* This process is also called as Phyto-extraction or Phyto-sequestration. This process uses plants and algae to remove contaminants from soil and water by producing harvestable plant biomass. The roots sorb the nutrients and other substances from soil and water and concentrate it above ground in plant biomass.
3. *Phyto-Degradation:* Phyto-Degradation also called as Phyto-Transformation is the process in which the plants metabolize and destroy the contaminants within the plant tissues.
4. *Phyto-Volatilization:* Phyto-Volatilization is the process of removal of contaminants from soil and water by releasing them into air, as a result of Phyto-Transformation to more volatile and less polluting substances.
5. *Phyto-Stimulation:* Phyto-Stimulation is the degradation of organic contaminants by the microbial activity of organisms that are associated with roots. In order to stimulate the microbial activity, plants release carbohydrates and acids, which results in biodegradation of the organic contaminants.
6. *Rhizofiltration:* Rhizofiltration is the process in which the plants release natural substances through its roots system and supply the nutrients to the microorganisms present in the soil. The microorganisms help in biological degradation of contaminants in the soil layer.

III. METHODOLOGY

A. Introduction

This chapter presents about the phytoremediation of the aquafarm effluents after the culture period. Phytoremediation technique has been used in treatment of the effluents. In the present study floating aquatic plants such as Water Hyacinth, Water Lettuce have been used in the treatment of the effluents. Effluents are taken in a plastic tub and the aquatic plants have been placed in them. Along with initial biomass of plants, for every 7 days, 15 days, 21 days, and 30 days the gain in biomass of the plants is recorded along with water quality parameters such as pH, Dissolved Oxygen, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia, Nitrites, Nitrates, Phosphates. The growth rate of the plant is expressed in terms biomass of plant which is determined as density in units of wet plant mass per unit surface area. The effluent treatment system is also design for the existing farm.

B. Sampling Point

Every fortnight, the samples for the analysis of pond discharges were collected at the outlet of the ponds. The samples were collected during the culture period every fortnightly and during harvest when entire pond is drained off. There are two types of sampling, Grab sampling and Composite sampling. In the present study Grab sampling is used. A Grab sampling is a type of sampling in which a discrete sample is collected at specific location at a certain point of time. The outlet of the ponds, which is a concrete structure, is provided with a cap at the bottom. The samples were collected in air tight sampling bottles.

C. Factors to be considered during selection of aquatic plants

1. Biomass production: The pollutant removal rate depends on the plant biomass harvested and concentration of pollutant in plant. Higher the plant biomass and pollutant concentration in plant, the higher is the pollutant removal rate.
2. Uptake of organic and inorganic pollutants.
3. Growth rate: Growth rate can be presented in two ways. In the first way, growth rate of plant is calculated by reporting the percentage of water surface the plant covers for a period of time. In the second way, growth rate of plant is calculated by reporting plant density in units of wet plant mass per unit surface area. In the present study second way is chosen to calculate growth rate of plant.
4. Easiness of management and harvest.

D. Experimental apparatus

1. *Plastic Tub:* In the present study the phytoremediation technique has been used in the treatment of the aqua farm effluents. It is carried out by using a plastic tub filled with the wastewater after the harvest of the aqua farm. A plastic tub of dimensions 100 cm x 100cm x 30cm which resembles a pond, is selected to conduct experiments. The bottom of the tub is filled with a thin layer of pond soil. The experiments were conducted in open air space in the study area. The water is collected at the outlet provided for the tub. For every 2 or 3 days, about 2 to 3 hours, air is supplied to the water in the tub with the help of aquarium air pump, as the oxygen levels depletes because of decomposition of organic matter. Known amount of aquatic plant biomass is introduced into the tub. Every week the gain in biomass of the plants are recorded along with the water quality parameters such as pH, Dissolved Oxygen, TSS, TDS, BOD, COD, Ammonia, Nitrites, Nitrates, Phosphates.
2. *Eichhornia Crassipes:* Eichhornia Crassipes which is also known as water hyacinth, is a hydrophyte plant native to tropical and sub-tropical regions of amazon basin in South America. They belong to the Plantae kingdom, Pontederiaceae Family, Eichhornia Genus. It was named after the famous Prussian politician J.E.F.F Eichhorn. It is a free-floating perennial aquatic weed. It has spongy, long and bulbous stem which floats on water with the help of buoyance bulb at its base. These aquatic plants have high growth rate and complex root structure and forms dense, interlocking mats. Water hyacinth is one of the known fastest growing plants which forms daughter plants by the help of runners or stolons. It reproduces both sexually and asexually. Water hyacinth grows between the temperature ranges of 12^0C – 40^0C with its optimal growth temperatures 25^0C – 30^0C.
3. *Pistia Stratiotes:* Pistia Stratiotes which is also known as Water Lettuce, is a hydrophyte plant; belongs to Plantae Kingdom, Araceae Family, Pistia Genus. It is also called as Water Cabbage, Nile Cabbage, Shell flower. It is light green in color, having parallel veins, wavy margins and form basket like structures which have ability to trap air bubbles, helping in increasing plants buoyancy. It is a perennial monocotyledon which floats on water surface having thick soft leaves that form rosette and its roots hanging submerged beneath floating leaves. Water Lettuce grows between the temperature ranges of 20^0C – 39^0C. It is extremely frost sensitive and non-winter hard plant which finds difficult to grow at low temperatures. It requires solar radiation for growth. In dry season, growth rate of Water Lettuce is slightly higher than Water Hyacinth.

IV. RESULTS

A. Phytoremediation with Eichhornia Crassipes

The wastewater from the pond during harvest is taken in our experimental setup, i.e. plastic tub. Known amount of Water Hyacinth biomass is placed in the tub. Water quality is tested initially, 7 days, 15 days, 21 days and 30 days by collecting water from the tub near the outlet at bottom of the tub; the variation in water quality parameters and gain in biomass is reported in Table III and Table V respectively and corresponding graphs are plotted as shown in Fig. 2 and Fig. 4.

TABLE III
VARIATION OF PARAMETERS DURING PHYTOREMEDIATION WITH EICHHORNIA CRASSIPES

S.No.	Parameter	0 days (Initial)	7 Days	15 Days	21 Days	30 Days	% Removal
1	pH	6.75	6.51	6.84	7.0	7.32	-
2	DO	1.6	2.1	2.3	2.5	3.8	-
3	Total Suspended Solids (ppm)	1478	1018	557	226	170	88.45
4	Total Dissolved Solids (ppm)	2034	1798	1432	1257	780	61.65
5	Biochemical Oxygen Demand (ppm)	224	193	119	62	18	91.96
6	Chemical Oxygen Demand (ppm)	288	216	164	109	48	83.33
7	Ammonia (ppm)	8.47	5.98	3.73	1.29	0.63	92.56
8	Nitrite (ppm)	2.42	2.19	1.75	0.98	0.68	71.9
9	Nitrate (ppm)	3.68	3.24	2.97	1.58	0.75	79.6
10	Phosphates (ppm)	10.6	7.1	5.2	2.1	0.6	94.33
11	Biomass in grams	135	450	735	882	1068	-

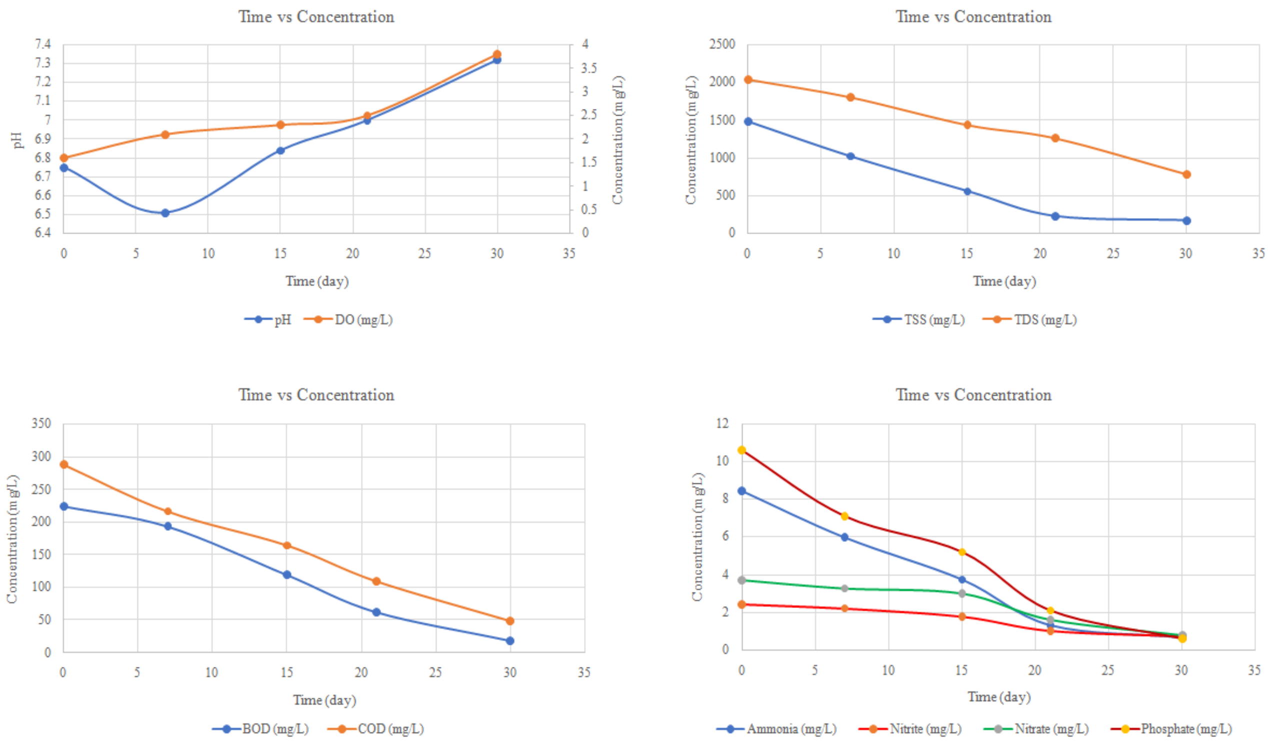

Fig. 2 Graphs showing variation in parameters by using Water Hyacinth

B. Phytoremediation with Pistia Stratiotes

The effluent from the pond during harvest is taken in our experimental setup, i.e. plastic tub. Known amount of Water Lettuce biomass is placed in the tub. Water quality is tested initially, 7 days, 15 days, 21 days and 30 days by collecting water from the tub near the outlet at bottom of the tub; the variation in water quality parameters and gain in biomass is reported in Table IV and Table V respectively and corresponding graphs are plotted as shown in Fig. 3 and Fig. 4.

TABLE IV
VARIATION OF PARAMETERS DURING PHYTOREMEDIATION WITH PISTIA STRATIOTES

S.No.	Parameter	0 days (Initial)	7 Days	15 Days	21 Days	30 Days	% Removal
1	pH	6.75	6.38	6.65	6.94	7.12	-
2	DO	1.6	2.0	2.2	2.6	3.4	-
3	Total Suspended Solids (ppm)	1478	1132	629	150	125	91.54
4	Total Dissolved Solids (ppm)	2034	1812	1417	1035	732	64.01
5	Biochemical Oxygen Demand(ppm)	224	187	125	58	15	93.3
6	Chemical Oxygen Demand (ppm)	288	226	158	112	62	78.47
7	Ammonia (ppm)	8.47	5.53	2.98	1.12	0.45	94.68
8	Nitrite (ppm)	2.42	2.34	1.68	0.84	0.51	78.9
9	Nitrate (ppm)	3.68	3.29	2.85	1.42	0.63	82.9
10	Phosphates (ppm)	10.6	7.3	4.8	1.6	0.2	98.11
11	Biomass in grams	110	395	768	921	1092	

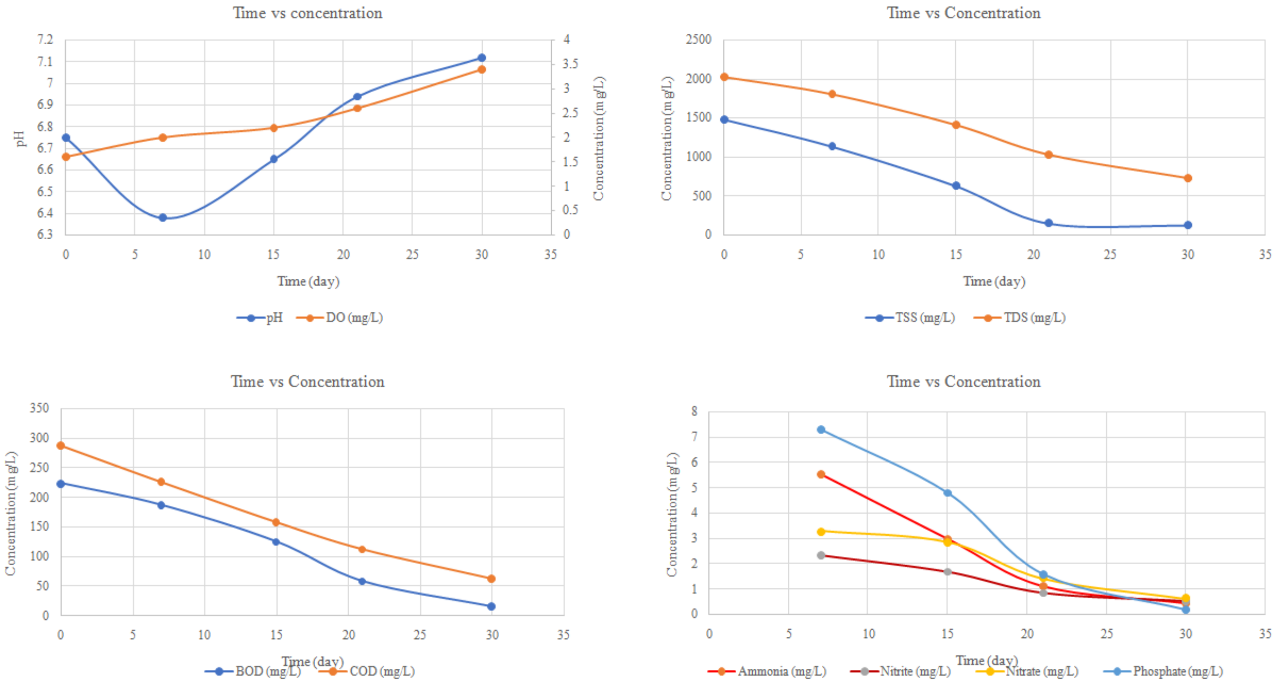

Fig. 3 Graphs showing variation in parameters by using Water Lettuce

C. Biomass Production

The plant growth rate is measured in terms of biomass gain. Biomass gain of plant is calculated by reporting plant density in units of wet plant mass per unit surface area. Here surface area experimental setup is 100 cm x 100 cm, i.e. $1m^2$. Hence our calculated biomass is wet weight of plant per $1m^2$ of surface area. The values of biomass are reported in Table V and corresponding graph is plotted as shown in Fig. 4. As the plant biomass is made up of organic matter, it can be used in the generation of bioenergy.

TABLE V
VARIATION IN BIOMASS DURING PHYTOREMEDIATION PROCESS

S.No.	Time	Biomass of Water Hyacinth in grams	Biomass of Water Lettuce in grams
1	Initial	135	110
2	7 days	450	395
3	15 days	735	768
4	21 days	882	921
5	30 days	1068	1092

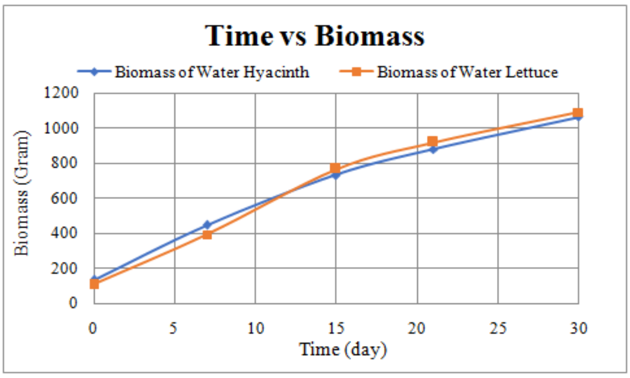

Fig. 3 showing variation in biomass during Phytoremediation

D. Design of Effluent Treatment System for the Existing farm at study area

In the present study, Effluent Treatment System (ETS) is designed based on theoretical assumptions for the farm at study area. All the necessary data is obtained from the Guidelines for designing Effluent Treatment System provided by Coastal Aquaculture Authority (CAA).

- Area of farm pond = 250(m) x 405(m) = 1,01,250 m^2
- Water Depth of farm pond = 1.3 m
- Volume of water in the pond = Area of pond x Water depth of pond
  = 1,01,250 x 1.3 = 1,31,625 m^3

Formula's used

- Terminal settling velocity of discrete particle (v_s) = g (S-1) d^2/ (18 x υ)
  - g: acceleration due to gravity
  - S: Specific gravity of particle
  - d: diameter of particle
  - υ: Kinematic Viscosity
- Detention time = Volume of pond/Q
- Surface Loading Rate (v_o) = Volume of water applied per unit time per unit surface area.

1. *Calculating dimensions of Effluent Treatment System*

For calculation of settling velocity(v_s) the following assumptions were made

- ❑ Diameter of particle(d) = 0.015 mm
- ❑ Specific Gravity of particle(S) = 2.5
- ❑ Kinematic viscosity (υ) = $1x10^{-2}$ stokes (1stoke=$1cm^2/s$)
  = 10^{-2} cm^2/s (1cm = 10mm)
  = 1 mm^2/s
- ❑ Acceleration due to gravity(g) = 9.81 m/s^2 = 9810 mm/s^2
- ❑ Terminal Settling velocity of discrete particle (v_s) = g (S-1) d^2/ (18 x υ)
  = 9810 (2.5-1) $(0.015)^2$/18x1
  = 0.183 mm/s
  = 0.183x24x60x60/ 1000m/day
  = 15.89 m/day

- For calculation of volume of sedimentation tank
- ❑ Surface loading rate (v_o) is the volume of water applied per unit time per unit surface area of settling tank (or) sedimentation tank.

v_o = Q/surface area of settling tank

For 100% removal of particles $v_s = v_o$

$v_o = v_s$ = 15.89 = 1,31,625/surface area of settling tank

Surface area = 1,31,625/15.89

= 8283.5 m^2

Assume baffle walls area = 500 m^2

Surface area of settling tank excluding baffle walls = 8283.5 m^2 – 500 m^2

= 7783.5 m^2

Therefore,

Surface area of settling tank (L x B) = 7783.4 m^2

Assume, L:B = 4:1; L = 4 x B

B = 44.1 m ~ 44 m

L = 176.4 m ~ 176 m

Assume water depth in settling pond = 1.2 m

Free board = 0.5 m

Volume of settling pond = 176m x 44m x 1.7m

= 13,164.8 m^3

Therefore provide,

Length of settling pond = 176 m

Width of settling pond = 44 m

Depth of settling pond = 1.7 m

- Bio pond

It is better to provide two bio ponds. Therefore, provide bio ponds each of size

Length of Bio-pond = 72 m

Width of Bio-pond = 60 m

Depth of Bio-pond with free board = 1.5 m

Volume of Bio-pond = 72m x 60m x 1.5m = 6480 m^3

Therefore, provide two Bio-ponds each of volume 6480 m^3

- Aeration Pond

Provide one aeration pond of dimensions,

Length of aeration pond = 72 m

Width of aeration pond = 40 m

Depth of aeration pond with free board = 1.7 m

Volume of Aeration Pond = 72m x 40m x 1.7m = 4896 m^3

Provide aeration pond of volume 4896 m^3

TABLE VI
WATER EXCHANGE SCHEDULE FOR FARMS PRACTICING RECIRCULATION SYSTEM

Month	Volume of water exchange
1	10% in 15 days
2	10% in 15 days
3	20% in 15 days
4	20% in 10 days

2. Water exchange for farm

The following is the theoretical calculation which shows how to exchange water from the farm in order to achieve zero discharge system. The calculation shows the water exchange schedule for the farm so as to achieve zero liquid discharge system. The water is recirculated back to the farm without being discharged. Table VI shows water exchange schedule guidelines provided by Coastal Aquaculture Authority.

- Month-1

  Total volume of water available in the pond = 1,31,625 m^3
  Volume of water exchange (10% in 15 Days) = 1,31,625 x 0.1
  = 13,162.5 m^3
  Volume of water per day = 13,162.5/15 = 877.5 m^3/day
  Retention time available in
  - ❑ Sedimentation pond = 13,164/877.5 = 15 days
  - ❑ Bio-pond = 6480/877.5 = 7.38 days
  - ❑ Aeration pond = 4896/877.5 = 5.58 days
- Month-2

  Total volume of water available in the pond = 1,31,625 m^3
  Volume of water exchange (10% in 15 Days) = 1,31,625 x 0.1
  = 13,162.5 m^3
  Volume of water per day = 13,162.5/15 = 877.5 m^3/day
  Retention time available in
  - ❑ Sedimentation pond = 13,164/877.5 = 15 days
  - ❑ Bio-pond = 6480/877.5 = 7.38 days
  - ❑ Aeration pond = 4896/877.5 = 5.58 days
- Month-3

  Total volume of water available in the pond = 1,31,625 m^3
  Volume of water exchange (20% in 15 Days) = 1,31,625 x 0.2
  = 26,325 m^3
  Volume of water per day = 26,315/15 = 1755 m^3/day
  Retention time available in
  - ❑ Sedimentation pond = 13,164/1755 = 7.5 days
  - ❑ Bio-pond = 6480/1755 = 3.69 days
  - ❑ Aeration pond = 4896/1755 = 2.789 days
- Month-4

  Total volume of water available in the pond = 1,31,625 m^3
  Volume of water exchange (20% in 10 Days) = 1,31,625 x 0.2
  = 26,325 m^3
  Volume of water per day = 26,315/10 = 2631.5 m^3/day
  Retention time available in
  - ❑ Sedimentation pond = 13,164/2631.5 = 5 days
  - ❑ Bio-pond = 6480/2631.5 = 2.46 days
  - ❑ Aeration pond = 4896/2631.5 = 1.86 days

- Harvest

  The water from the culture pond is drained up to a depth of 0.65 m, starting from 10 days prior to harvest.
  Volume of water released in 10 days = 250m x 405m x 0.65m = 65,812.5 m^3
  Volume of water to be released per day = 65,812.5/10 = 6,581.25 m^3
  Retention time available in
  - ❑ Sedimentation pond = 13,164/6581.25 = 2 days
  - ❑ Bio-pond = 6480/6581.25 = 0.98 days
  - ❑ Aeration pond = 4896/6581.25 = 0.74 days

3. Layout of Effluent Treatment System

The Effluent Treatment System consists of Sedimentation Pond, 2 No's of Bio-Pond, Aeration Pond. It also consists of a Drain Canal carrying wastewater from farms during culture period and harvest, Sump Pit, Pump House, Baffle Walls. Fig. 5 shows the layout of the Effluent Treatment System (ETS). The water enters the sedimentation pond from the sump pit with the help of pumphouse if necessary, else gravity flow is preferred. In the sedimentation pond the flow velocity of the wastewater is controlled with the help of baffle walls, providing longer length to travel, thereby a portion of the suspended particles settles as the flow velocity is controlled. Later the water enters the Bio-ponds where the Phytoremediation plants are used. Then water is allowed to pass through the aeration ponds, where paddle wheel aerators are placed for the aeration of the water. From the aeration pond water is recirculated back to the farms.

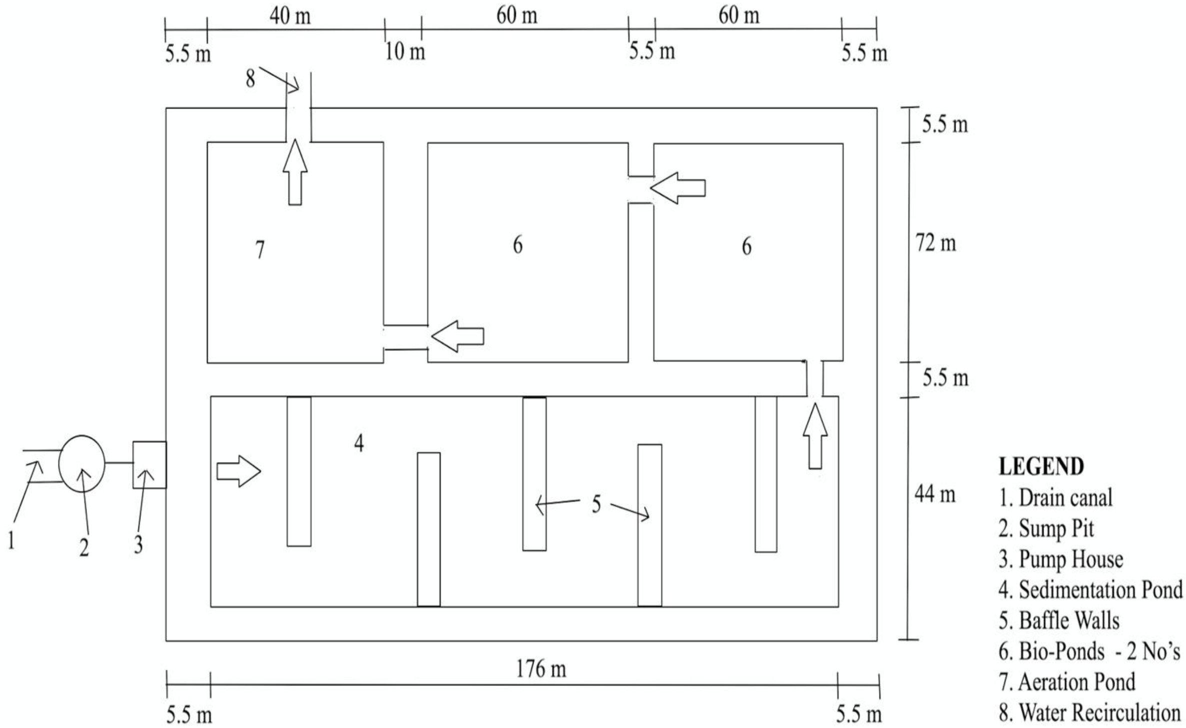

Fig. 5 Layout Plan of Effluent Treatment System

V. CONCLUSIONS

From the above results the following conclusions can be drawn

1. As the water is being discharged without treatment, the receiving bodies and surrounding environment is getting disturbed. By using Phytoremediation technique, the water can achieve required degree of contaminant removal and can be recirculated back to the aquafarms, there by achieving zero liquid discharge system. Water is said to be conserved.
2. Advanced recirculating systems are necessary as the aquaculture is depended wholly on water. Instead of releasing the water into water bodies during and after culture period; and filling the ponds again from ground water sources and surface water sources again back into ponds for next crop season; recirculation is preferred as the same water after treatment is being recirculated and saving the earth from water scarcity. Coastal mangroves can be maintained healthy.
3. Ground water levels can be maintained and ground water salinization can be reduced as extraction of ground water gets reduced due to recirculation.
4. Phytoremediation technique is very cheap and easy to operate as the aquatic plants used can be easily found in the surrounding environment and do not require any external support to aid in the plant growth.
5. Water Lettuce has removal efficiencies of 91.54% and 64.01% for TSS and TDS respectively which is higher than that achieved by Water Hyacinth having efficiencies 88.45% and 61.65% for TSS and TDS respectively.
6. A higher BOD removal efficiency of 93.3% was achieved by using Water Lettuce than by using Water Hyacinth which achieved efficiency of 91.96%.
7. A higher COD removal efficiency of 83.33% was achieved by using Water Hyacinth. Water Lettuce removed only 78.47% of COD.
8. By using Water Lettuce; removal efficiencies of 94.68% for ammonia, 78.9% for nitrites, 82.9% for nitrates was achieved which is higher than that achieved by Water Hyacinth. By using Water Hyacinth; removal efficiencies of 92.56% for ammonia, 71.9% for nitrites, 79.6% for nitrates was recorded.
9. The phosphates removal efficiency was 98.11% by using Water Lettuce which was higher than that achieved by Water Hyacinth having efficiency 94.33%.
10. The Total Nitrogen (which is sum of organic nitrogen, ammonia nitrogen, nitrite nitrogen, nitrate nitrogen) and phosphates removal was higher by using Water Lettuce.
11. The biomass gain by using Water Lettuce was 982 grams/m^2 per 1m x 1m surface area of tub which was higher than the gain achieved by Water Hyacinth which was 933 grams/m^2 per 1m x 1m surface area of tub.
12. As the plants biomass is made up of organic rich matter, it can be used in generation of biofuel which is renewable source of energy and environmental friendly technology.

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