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Evaluation of reuse of shrimp farm effluent after chemical and biological treatments

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ABSTRACT

Possibility of reusing shrimp farm effluent water was evaluated after treatment of the water using chemical agents like calcium oxide (quick lime), ferric chloride, ferric aluminium sulphate (ferric alum) and fly ash. Among the chemicals used, treatments with fly ash (52.80%), quick lime (61.01%) and fly ash (72.5%) were found effective for the removal of ammonia, phosphate and for reduction in chemical oxygen demand (COD) respectively. In biological process, microalga *Chlorella salina* and the seaweed *Ulva reticulata* were tried. At the end of culture, highest net photosynthesis and assimilation number obtained from fly ash was 12.98 ± 0.096 g m^{-3} h^{-1} and 25.01 respectively. Level of ammonia and phosphate was drastically reduced from 152.01 to 1.18 µg at-N l^{-1} and 262 to 0.0719 µg at-P l^{-1} respectively in the waste water treated with fly ash cum microalgal culture. COD level was reduced from 102 to 5.31mg l^{-1} after treating the waste water with ferric chloride cum microalgal culture. The raw waste water yielded higher production of *Ulva* (7.74 g wet weight) followed by fly ash (7.26 g wet weight) and at the end of the culture period nitrogen concentration was 1.52 µg at-N l^{-1}. No production of *Ulva* was registered from the waste water treated with lime, alum and ferric chloride. In culture experiment with post-larvae of the shrimp *Fenneropenaeus indicus*, fly ash treated (8.25%) and fly ash cum algal cultured waste water (8.56%) showed higher net growth efficiency. The larvae did not survive in other chemically treated waters.

Keywords: Chemical treatment, *Chlorella salina*, Shrimp farm effluent, *Ulva reticulata*, Waste water treatment

Introduction

Shrimp culture is one of the most successful aquafarming practice in India. Though earlier, shrimp farming was perceived as a clean industry (Weston, 1991), due to rapid expansion with high stocking density, the waste water or effluent of the shrimp farms have become a major source of pollution in marine ecosystems (Hargreaves, 1998). The effluent normally contains high level of suspended solids and phytoplankton (Ziemann *et al.*, 1992) and lower levels of nutrients (Muir, 1982). The major nutrient present in the shrimp farm waste water is ammonia while phosphate is more in sewage (Macintosh and Phillips, 1992). Studies on the impact of shrimp farm effluents on the ecology of aquatic systems is very meagre (Pillay, 1992). The untreated effluents from shrimp farms may cause eutrophication, increased organic load and turbidity in the surrounding environment. The treatment of these waste waters receives importance owing to its role in avoiding contamination of environment and also its potential reuse for aquaculture purposes.

Traditional methods of waste water treatment are less effective and more expensive when used for treating shrimp farm waste water (Hopkins *et al.*, 1995). The waste water can be treated in many ways including filtration, chemical and biological processes. The methods include those using different kinds of fixed film biological filters (Klemtson and Rogers, 1985) for the removal of ammonia and other chemicals like ferric chloride. Lime and clay are used for removal of biological oxygen demand (BOD) (Limprich, 1996). Similarly alum, magnesium carbonate and activated charcoal are used to remove chemical oxygen demand (COD) of waste waters (Rana and Palria, 1987). An attempt was made to remove the organic matter in shrimp pond effluents using fly ash by Saravanan *et al.* (1997). Macroalgae are effective biological filters for treating shrimp pond waste waters through removal of suspended particulates and nutrients (Shpigel *et al.*, 1993). Seaweeds such as *Ulva reticulata* (Neori *et al.*, 1991) and *Gracillaria* sp. (Sudhakaran, 1995) can also be used to treat shrimp farm effluent. Aim of the present study was to evaluate the reuse of shrimp farm effluents for aquaculture purpose employing chemical and biological treatment methods.

Materials and methods

The study was conducted at Fisheries College and Research Institute, Thoothukudi during the year 2003. The waste water samples required for the present study was collected from M/s. MIL shrimp farm, Vaipar, Thoothukudi, Tamil Nadu, India. The collected samples were stored in refrigerated condition. The stored water samples were later treated by both chemical and biological methods. In chemical treatment, calcium oxide (quick lime), ferric alum, ferric chloride and fly ash were used. The dosages of various chemical agents were determined based on trial and error and based on previous studies conducted in the Institute for treating waste water from processing plants and sewage (Jude, 1993; Sudhakaran, 1995; Deeba, 1998; Vijaya Bhaskar, 2002).

Treatment with quick lime

Commercial grade quick lime (CaO) containing 24.39 g of 100% pure CaO was chosen. The chosen CaO was prepared in six different concentrations of 100 mg l^{-1}, 200 mg l^{-1}, 400 mg l^{-1}, 600 mg l^{-1}, 700 mg l^{-1} and 800 mg l^{-1}. The above different concentrated agents were added to one litre of waste water and aerated vigorously for one hour (Deeba, 1998). After the treatment, the values of highest percentage of removal of inorganic phosphorous (PO_4^{-2}), ammonia (NH_3) and chemical oxygen demand (COD) were determined individually.

Treatment with ferric alum

The optimum quantity of ferric alum required for effective removal of ammonia, phosphate and COD was determined by treating with ferric alum at different concentrations *viz.*, 50 mgl^{-1}, 100 mg l^{-1}, 200 mg l^{-1}, 400 mg l^{-1} and 500 mg l^{-1}. These were added to containers holding 1 litre of waste water and aerated vigorously for one hour. After the treatment, as done in the previous case, the values of maximum percentage removal of inorganic phosphorous (PO_4^{-2}), ammonia (NH_3) and COD were recorded individually.

Treatment with ferric chloride

The efficacy of ferric chloride in effecting the highest percentage removal of ammonia, phosphate and COD were assessed by adopting five different concentrations such as 50 mg l^{-1}, 100 mg l^{-1}, 200 mg l^{-1}, 400 mg l^{-1} and 500 mg l^{-1}. The waste water sample was treated with ferric chloride and aerated heavily for one hour. Later, the percentage removal of phosphate, ammonia and COD from the waste water were determined.

Treatment with fly ash

Six different doses of fly ash *viz.,* 10 g l^{-1}, 20 g l^{-1}, 40 g l^{-1}, 60 g l^{-1}, 80 g l^{-1} and 100 g l^{-1} were tested to study the highest percentage removal of phosphate, ammonia and COD. All the treatments were thoroughly agitated using a stirrer or shaker since the quantity of fly ash used for effluent treatment was above 10 g l^{-1}.

After treating the waste water with different kinds of chemical agents, the clear supernatant water was decanted and filtered using membrane filter of 0.45 µ porosity. When ever large quantity of clear water was required, the same was filtered again using 0.45 µ filter paper. Many researchers used sand filter to remove the flocculants from the waste waters before treatment (Weinberg and Narkis, 1987; Jude, 1993; Vijaya Bhaskar, 2002)

The pH of the clear waters treated with different chemicals was determined using pH meter before initiating the biological treatment. The waste water treated with quick lime had pH of above 7.5. It could be achieved with repeated aeration till all calcium hydroxide (CaOH) got converted into insoluble calcium carbonate ($CaCO_3$). Where as, ferric alum treated water had a low pH of below 6.5 and hence quick lime was added to raise the pH upto 7.5. Water treated with fly ash and ferric chloride did not show any pH variations. One ml of micronutrient was added to the treated water for enhancing microalgal growth for further biological treatment. Phosphate deficiency was restricted in all four chemical treated waters by adding potassium dihydrogen phosphate at a concentration of 750 µg l^{-1}.

Biological treatments

Chemically treated clear water was again treated biologically adopting different methods. As a first stage of biological treatment, the raw waste water and chemically treated waste waters were aerated well and placed in refrigerator for five days to destroy the existing plankton in the waste water. Aeration was given to create aerobic condition in the raw waste water for denitrification or sulphate reduction. The pH of the chemically treated water was maintained as 7.5 which facilitated good growth of algae. After checking the pH of the waters, 20 ml of a culture of pure strain of the microalga *Chlorella salina* (obtained from the laboratory of Central Marine Fisheries Research Institute, Thoothukudi) was inoculated into the chemically treated clear waters. The microalga inoculated waters were placed in the laboratory for one week and the growth was monitored on a daily basis. Apart from the microalgal culture, the seaweed *Ulva reticulata* was allowed to grow in both raw waste water and chemically treated algal cultured waters for a period of four days. During these experiments, multiplication rate of microalgae and production rate of seaweed were estimated. The prime objective of using this seaweed in the experiment was to compare the growth efficiency of micro and macro-vegetation in treated waste waters. Assimilation number which is the ratio of net photosynthesis to chlorophyll '*a*' content was worked out as it indicates the physiological status of the algal form. Net photosynthesis was not estimated as the weed stopped growth immediately after the total depletion of nutrients.

Feed trial

Feed trial was conducted with the objective of determining the suitability of chemically and biologically treated waste waters for shrimp culture practices. All the four chemically and biologically treated waste waters were taken for this experiment along with aged seawater as control, maintaining salinity of 34.8 ppt with the help of distilled water. The pH was adjusted to 7 - 7.5 using quick lime. The waters were intensively aerated for two days. After aeration, the algae settled at the bottom of the containers were removed. Feed trials were conducted in all these sixt ypes of waters by introducing 10 post-larvae each of *Fenneropenaeus indicus* having the mean weight of 0.802 ± 0.006 g with replications. The animals were fed *ad libitum* with standard feed prepared in the laboratory , having 20% protein. This experiment was conducted for 21 days in the laboratory with sufficient water exchange. Aeration was provided throughout the experimental period to all the experimental tanks. During the experiment, growth of the fishes was recorded in every three days based on the quantity of feed consumed, assimilation rate and feacal matter released. Efficiency of energy utilisation in shrimp larvae was estimated using standard procedures as given by Ramadhas and Sumitra (1979). Besides the growth estimation, the dry weight increment, gross growth efficiency (K1) and net growth efficiency (K2) were estimated in all growth trials using standard procedures (Santhanam, 1981).

All the data obtained from the trials conducted were analysed statistically using Analysis of Variance (ANOVA) technique and students t-test to study the significant effect of various chemical and biological treatments of waste water and growth performance of *F. indicus*.

Results and discussion

Shrimp farm waste includes a mixture of gases, liquids, semi-solids and other solid forms. It contains high level of nutrients, pollutants and pathogens which causes eutrophication and increases oxygen demand in the adjacent aquatic environment if discharged without any treatment. So a systematic waste management strategy that includes treatment, disposal and recycling is needed for sustainable shrimp farming management (Latt, 2002). Few methods of bioprocessing of these waters are available while chemical methods are not yet standardised. Deeba (1998) and Vijaya Bhaskar (2002) tried to treat seafood processing plant effluent and sewage water respectively using chemicals like calcium oxide, ferric chloride, ferric alum and fly ash. Subha and Deeba (1998) reported that chemical treatment of the waste water of shrimp farm with zeolite and fly ash highly improved its water quality. The present study also aimed at treating the shrimp farm waste waters using the same chemicals and other two bio-processing methods.

The physicochemical characteristics of brackishwater shrimp farm effluent are given in Table 1. As the effluent contained high organic load and less plant nutrients, it is essential to treat the waste waters inorder to reuse it for aquaculture.

Table 1. Physicochemical characteristics of the raw waste water from brackishwater shrimp farm

Parameter	Value
Hardness (mg l^{-1})	34.80
pH	8.34
Dissolved oxygen (ml l^{-1})	3.41
Chemical oxygen demand (mg l^{-1})	102.00
Biological oxygen demand (mg l^{-1})	68.20
Suspend solids (mg l^{-1})	49.81
Phosphate (µg at-P l^{-1})	262.00
Ammonia (µ at-N g l^{-1})	152.01
Nitrite (µg at-N l^{-1})	32.27
Nitrate (µg at-N l^{-1})	81.53

Impact of chemical treatment

Ammonia (NH_3): Ammonia content of raw effluent was 152.01 µg at-N l^{-1}. The extent of removal of ammonia varied in each treatment. The results are presented in Table 2. The highest quantity of ammonia (52.80%) was removed by fly ash treatment while it was least (21.20 %) in ferric chloride treatment. The fly ash treated water registered lowest level of ammonia (71.754 µg at-N l^{-1}) and the highest was seen with ferric chloride (119.78 µg at-N l^{-1}) treatment. Ammonia removal efficiency recorded for various chemical tested are as follows.

NH_3 removal (%) = 13.81 + 0.0467 (concentration of lime mg l^{-1}) = 24.261 + 0.0615 (concentration of Ferric alum mg l^{-1}) = 2.139 + 0.042 (concentration of $FeCl_3$ mg l^{-1}) = 12.833 + 0.477 (concentration of fly ash g l^{-1}).

The ammonia could also be eliminated using burnt lime (Deeba, 1998) as solubility of ammonia in water is decided by both pH and temperature (Boyd and Pillai, 1984). Ammonia could be stripped off through effective aeration at hyper pH

b) Phosphate (PO_4): Raw water contained a phosphate level of 262.0 µg at-P l^{-1}. The levels of removal of phosphate in different treatments are given in Table 2. The removal of phosphate was high in quick lime treatment (61.01%) and low in fly ash treatment (22.81%). Lime and fly ash removed the phosphate significantly ($p<0.001$) followed by ferric chloride ($p<0.02$) and ferric alum ($p<0.05$). Similarly significant effects between chemical agents in removal of phosphate was also observed ($p<0.001$). The lowest and highest level of phosphate was registered in the treatment of fly ash (202.24 μg at-P l^{-1}) and quick lime (102.154 μg at-P l^{-1}) respectively. The correlation observed between percentage removal of phosphate and treatment of lime, fly ash, ferric chloride and alum were 0.969, 0.953, 0.897 and 0.824 respectively. The relationship between phosphate removal and different treatments are:

PO_4 removal (%) = 22.873 + 0.0487 (Concentration of lime mg l^{-1}) = 24.418 + 0.0624 (Concentration of Ferric alum mg l^{-1}) = 24.483 + 0.0317 (Concentration of $FeCl_3$ mg l^{-1}) = 9.880 + 0.1335 (Concentration of fly ash g l^{-1}).

Reaction of burnt lime with the waste water increased the pH through dissociation of calcium hydroxide into calcium and hydroxyl ions. The elevated pH caused flocculation and precipitation of both soluble and particulate matter (Stumm and Morgan, 1996). Stumm and Lee (1961) affirmed that addition of lime to waste water would lead to the formation of two types of insoluble phosphate compounds as mentioned below:

$$3Ca^2 + 2PO_4^{3-} \rightarrow Ca_3\,(PO_4)_2$$
$$Ca_3\,(PO_4)_2 \text{ Hydration } Ca_3\,(PO_4)_2\,(OH)_5$$

Fly ash and lime performed well in highest percentage removal of ammonia and phosphate respectively from the waste water.

c) Chemical oxygen demand (COD): Raw effluent had a COD level of 102 mg l^{-1}. The reduction of COD from raw effluent was found high (72.5%) in fly ash treated water and low (57%) in ferric chloride treatment. Percentage reduction of COD in different treatments are given in Table 2. Fly ash and lime reduced COD significantly ($p<0.001$) followed by other chemical agents. However, no significant difference in reduction of COD could be observed in chemical agents except in case of lime and ferric chloride ($p<0.01$).

It is apparent that fly ash removed highest percent of ammonia and COD whereas quick lime effected phosphate removal. In the case of organic matter removal from waste water, fly ash and alum were equally effective. Ferric alum dissociated in water to yield aluminium and ferric ions and these ions reacts with $H_2PO_4^-$ to give insoluble phosphates of aluminium and iron as in the reaction mentioned below:

$$Al^{3+} + H_2PO_4^- + 2H_2O \rightarrow AlPO_4\,2H_2O + 2H^+$$
$$Fe^{3+} + H_2PO_4^- + 2H_2O \rightarrow FePO_4\,2H_2O + 2H^+$$

As both aluminium and ferric ions removed the phosphate present in the waste water, ferric alum performed almost equally well with quick lime in quantitative removal of phosphate. Al^{3+} and Fe^{3+} coagulants effectively removed the humic and fulvic acids from the shrimp farm waste water and these are well known to remove even suspended particulate matter from waste water (Stumm and Morgan, 1996). Aluminium and ferric irons were converted into aluminium hydroxide and ferric hydroxide after reacting with water. Ferric hydroxide is reported to be a very good scavenger of organic matter as well as metal ions

Table 2. Quantity of ammonia, phosphate and COD registered in different chemical and biological treatment of waste water of brackishwater shrimp farm

Types of treatment	Parameters	Lime	Alum	Ferric chloride	Fly ash
Raw waste water	Ammonia (μg. at-Nl^{-1})	152.01	152.01	152.01	152.01
	Phosphate (μg. at-P l^{-1})	262.00	262.00	262.00	262.00
	COD (mg l^{-1})	102.00	102.00	102.00	102.00
Chemical treatment	Ammonia (μg. at-N l^{-1})	*79.15	*75.425	119.78	*71.754
	Phosphate (μg. at-P l^{-1})	**102.154	*²131.89	*¹162.13	**202.24
	COD (mg l^{-1})	**32.64	*²33.97	*¹43.86	**28.03
Biological treatment	Ammonia (μg. at-N l^{-1})	*11.48	**2.12	*9.24	**1.18
	Phosphate (μg. at-P l^{-1})	*0.79	**0.143	*0.628	**0.0719
	COD (mg l^{-1})	**5.85	**6.24	**5.31	**6.82

**: $p<0.001$ *: $p<0.01$ *¹: $p<0.02$ and *²: $p<0.05$

(Stumm and Lee, 1961). This scavenging nature of ferric alum encourages its usage as a water clarifier in aquaculture systems (Manimaran and Ramadhas, 2002).

In the case of ferric chloride, it disassociated into ferric ion which reacted with phosphate in the waste water to produce ferric phosphate. The ferric ions further reacted with applied bicarbonate and formed carbon dioxide, thereby reducing the pH. After some of the ferric ions reacted with water, it produced ferric hydroxide which acted as a good scavenger for the removal of organic matter (Vincent *et al*. 1987). It could be observed that ferric chloride performed inferiorly in removal of organic matter when compared to other chemical agents used in the study. Instead, the combination of ferric chloride with quick lime could have been a better alternative in precipitating the organic matter present in the waste water.

Fly ash served as a good agent in removal of ammonia, COD and organic matter from the waste water. The removal of organic matter by fly ash could be possible due to its high content of silica (Rathore *et al.*, 1985; Deb *et al.*, 1996). Further, the iron oxide coating present in the surface of the fly ash also might have played a role in removal of organic matter (Bresslin and Dudedall, 1987). Nevertheless, there is scarce information available about the removal of phosphate by fly ash. However, Subha and Deeba (1999) observed that fly ash was inferior to zeolite in removing the phosphate from shrimp farm effluent.

Biological treatment

The raw waste water inoculated with the micro alga *Chlorella salina* did not exhibit good development of chlorophyll '*a*' during the initial days of culture, eventhough it was good towards the end of the culture period. The average chlorophyll content recorded in a week period of culture was 0.525g m^{-3}. Similarly the developments of microalgae, inoculated in different chemically treated waters were also studied. Chlorophyll '*a*' content registered in a week old culture for both raw and chemically treated waste waters are given in Table 3.

There was significant increase in production of chlorophyll *a* in chemically treated waters ($p<0.01$) on daily basis. At the end of the seventh day, the highest net photosynthesis (12.98 ± 0.096 g m^{-3} h^{-1}) was observed from fly ash treated water, followed by alum (10.53 ± 0.06 g m^{-3} h^{-1}), ferric chloride (4.84 ± 0.065 gm^{-3}/h^{-1}) and lime water (4.47 ± 0.06 g m^{-3} h^{-1}) treated waters. The values of assimilation number registered in the different treatments ranged from 8.5 to 25.01. The highest assimilation number was from fly ash treated (25.01) water followed by alum (21.5), ferric chloride (11.8) and lime (11.15) treated ones. The daily net photosynthesis and assimilation numbers are given in Table 4. The assimilation number remained above 20 in both fly ash and alum treated waste water. It indicated the good physiological status of the algae as the assimilation number was above 5 (Curl and Small, 1965; Qasim *et al.*, 1969). It could be observed that chemically treated waste water did not pose any physiological stress to the algae during culture. The fly ash and alum treated waste waters favoured the process of organic production.

In biological treatment with microalgae, the highest and lowest level of ammonia was recorded in the treatment with quick lime (11.48 µg at-N l^{-1}) and fly ash (1.18 µg at-N l^{-1}) respectively. The same trend existed in phosphate removal with quick lime (0.79 µg at-Pl^{-1}) and fly ash (0.0719 µg at-P l^{-1}). The level of COD registered was high in fly ash (6.82 mg l^{-1}) and low in ferric chloride (5.31mg l^{-1}). In biological treatment, drastic reduction in all three parameters were observed. Significant difference observed in the removal of ammonia, phosphate and COD between raw waste water, biologically treated waters and chemical treatments (Table 2).

Many researchers tried algal culture for processing the waste water (Dunstan and Manzel, 1971; Manimaran *et al.*, 1990; Manimaran and Ramadhas, 2002). The better growth of *C. salina* was noticed in fly ash treated water compared to other chemically treated waters. It may be due to lack of nutrients present in the treated waters. Algal growth facilitated the removal of nitrogen and phosphate

Table 3. Production of chlorophyll '*a*' (g m^{-3}) from raw waste water and chemically treated waste water of brackishwater shrimp farm.

**Days	Raw waste water	*Lime	*Alum	*Ferric chloride	*Fly ash
Initial	0.124 ± 0.002	0.124 ± 0.002	0.124 ± 0.002	0.124 ± 0.002	0.124 ± 0.002
1	0.196 ± 0.002	0.148 ± 0.002	0.148 ± 0.002	0.158 ± 0.001	0.164 ± 0.001
2	0.384 ± 0.004	0.195 ± 0.001	0.220 ± 0.002	0.206 ± 0.010	0.225 ± 0.005
3	0.458 ± 0.014	0.212 ± 0.020	0.282 ± 0.010	0.246 ± 0.020	0.295 ± 0.015
4	0.522 ± 0.012	0.284 ± 0.010	0.321 ± 0.020	0.311 ± 0.020	0.342 ± 0.002
5	0.681 ± 0.015	0.320 ± 0.020	0.395 ± 0.010	0.362 ± 0.010	0.412 ± 0.001
6	0.738 ± 0.020	0.380 ± 0.001	0.420 ± 0.020	0.392 ± 0.020	0.498 ± 0.020
7	0.825 ± 0.040	0.401 ± 0.020	0.495 ± 0.040	0.411 ± 0.030	0.519 ± 0.030

**: $p<0.001$ *: $p<0.01$

from the chemically treated waste water by absorbing them for their growth. *Chlorella* performed well in removal of phosphate from the waste water since many of the chlorella species require large quantity of phosphorous for their growth (Chu, 1943).

Feed trial

Growth of shrimp larvae *Fenneropenaeus indicus* grown in different types of chemically treated waste water and chemical cum biologically treated waters are given in Table 5. Among the chemically treated waters, the fly ash treated water only favoured the growth of the shrimp larvae while the larvae did not survive beyond three days in other treated waters. The net growth efficiency of larvae was high in *Ulva* treated water (8.56%) followed by fly ash treated water (8.25%) and control (7.92%). The gross and net growth efficiency recorded in fly ash treated water and biologically treated water were higher than the control. Net growth efficiency varied between fly ash treated and biologically treated waters. The assimilation efficiency was high in fly ash treated water (94.78%) followed by *Ulva* treated (93.55) water and control (89.82).

Table 4. Production rate in net photosynthesis (g m^{-3} h^{-1}) and assimilation number (in parenthesis) from chemically treated waste water of brackishwater shrimp farm

**Days	*Lime	*Alum	*Ferric chloride	*Fly ash
Initial	1.12 ± 0.031 (9.05)	1.12 ± 0.031 (9.05)	1.12 ± 0.031 (9.05)	1.12 ± 0.035 (9.05)
1	1.36 ± 0.035 (9.25)	3.18 ± 0.032 (21.15)	1.29 ± 0.034 (8.50)	3.59 ± 0.035 (21.90)
2	1.87 ± 0.040 (9.62)	4.52 ± 0.039 (20.59)	1.905 ± 0.041 (9.25)	5.00 ± 0.042 (22.75)
3	2.10 ± 0.041 (9.95)	5.85 ± 0.045 (20.78)	2.43 ± 0.049 (9.89)	6.78 ± 0.049 (22.99)
4	2.91 ± 0.047 (10.25)	6.73 ± 0.049 (20.99)	3.26 ± 0.051 (10.5)	8.03 ± 0.053 (23.50)
5	3.37 ± 0.050 (10.55)	8.31 ± 0.051 (21.05)	3.92 ± 0.059 (10.85)	7.89 ± 0.059 (24.01)
6	4.16 ± 0.057 (10.95)	8.96 ± 0.058 (21.35)	4.46 ± 0.062 (11.39)	12.27 ± 0.065 (24.64)
7	4.47 ± 0.060 (11.15)	10.53 ± 0.061 (21.50)	4.84 ± 0.065 (11.80)	12.98 ± 0.096 (25.01)

**: ($p<0.001$) *: ($p<0.01$)

In another biological treatment, the seaweed *Ulva reticulata* was used to treat the raw and chemically treated waste waters and the production rate of *Ulva* was recorded. In the end of the culture period, the average recorded growth of *Ulva* in raw waste water was 7.74 g of wet weight while it was 7.26 g of wet weight in the waste water treated with fly ash with final nitrogen concentration of 1.52 µg at-N l^{-1}. The average weed growth in raw water and fly ash treated waters were 1.48 g day^{-1} and 1.46 g day^{-1} respectively. There were no growth of weed in lime, alum and ferric chloride treated waters. It could be attributed to the lack of essential nutrients in the treated waters. There was no significant difference in growth of *Ulva* between raw waste water and fly ash treated water. After the biological treatment, it was observed that phosphate was totally absent in the waste water despite drastic reduction in the concentration of ammonia. The seaweed might have utilised the nutrients for its growth.

The larvae of *F. indicus* showed higher growth rate in fly ash treated water followed by *Ulva* treated water with good assimilation efficiency. It could be due to high percentage removal of phosphate, ammonia and organic matter from the waste water. The gross and net growth efficiency recorded in the control water were the lowest

Table 5. Growth of shrimp post-larvae *Fenneropenaeus indicus* in waste water treated with flyash and seaweed *Ulva reticulata*

Parameters	Control	Fly ash treated	Seaweed treated
Initial average day weight (W_1) g	0.7765	0.7612	0.8510
Final average day weight (W_1) g	2.1615	2.1822	2.3790
Weighed mean ($W = W_2 - W_1/2$) g	1.469	1.4717	1.615
Production ($P = W_2 - W_1$) g	1.3857	1.4210	1.5281
Food consumption (C) g	19.48	18.171	19.08
Fecal output (F) g	1.198	0.948	1.229
Assimilation (A= C-F)	17.496	17.222	17.571
Metabolism (R = A-P)	16.11	15.801	16.323
Assimilation efficiency (A) %	89.82	94.78	93.55
Gross growth efficiency K_1 (P/C) %	7.11	7.82	8.01
Net growth efficiency K_2 (P/A) %	7.92	8.25	8.56
Relative growth rate per day (P/W/day) g	0.045	0.046	0.4505

among all treatments as it did not have required nutrients. There was total decomposition of algae and no growth of seaweed in most of the chemically treated waste waters except fly ash treated water which also did not favour the growth of shrimp larvae.

Almost all the four chemical treatments worked well in treating the waste water from the shrimp farm. These methods can be used for treating the waste water before releasing into the adjoining aquatic systems. Fly ash performed well compared to all other chemical agents tested. Biological method of processing of waste water after chemical treatment encourages the reuse of the treated waste water for further aquaculture practices.

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