Science Park Research Journal
ISSN 2321-8045
Impact Factor : 2.1005[UIF-2014]
Volume - 3 | Issue - 18| 12th Nov- 2015

PHYCOREMEDIATION OF FISH PROCESSED WASTE WATER FROM MANGALORE AND GOA, INDIA

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ABSTRACT:

A feasible, cost effective, cheap labour and eco-friendly method using microalgae in fish waste water treatment. In the regions of Mangalore and Goa, India, fishy stink foul odour from fishery industry causes public nuisances to the urban regions around the fishery industry and thus creating major problem to the fishery industry. The major task of our study is to treat fish processed waste water in order to reduce high organic content and also to reduce the stinky foul odour comes from it. Fish processed waste water was already reported to be the polluting agent for the aquatic environment and its surroundings. A consecutive chain of biological treatment methods initially anaerobic treatment followed by Aerobic, Primary and Microalgae treatment methods were established. In recent years, microalgae are involved in waste water treatment process such as sewage water treatment and dye waste water treatment etc. From our study, all the physio-chemical parameters were reduced along with fish odour in the final microalgae treatment method. Three microalgae consortia were involved in our work including, Chlorella vulgaris, Chroococcus sp. and Oscillatoria sp. in the treatment of fish processed waste water.

KEY WORDS: Fish waste water; Biological treatment; Microalgae treatment; Physio-chemical parameters.

1. INTRODUCTION :

Fishery products placed a significant role in the economy and social well being of nations worldwide. About 131 million tons of fish were produced in 2000 worldwide, of which 74 % was consumed by humans and the remaining 26 % was utilized for non-food products, for reduction to meal and oil (FAO, 2002). Filleting, Freezing, Drying, Fermenting, Canning and smoking are the common processes in fish processing plants (Palenzuela-Rollon, 1999). Huge water consumption in fish processing plants and high-strength waste water from such an industry are of great concern worldwide (Chowdhury et al., 2010). Waste water from fisheries is rich in lipids, oils and proteins; can be very high in Biochemical oxygen demand (BOD) and nitrogen content. Literature data from seafood processing showed a BOD production of 1-72.5 kg per tonne of product in Canada (Environment Canada, 1994). Since the waste water generated from fish processing plants, have not been receiving any severe attention (Islam et al., 2004).

Recent decades the fish processing industries are facing various problems of waste water disposal as well as pollution prevention regulations. The fish waste waters are considered the same impact as the sewage waste effluent which contains excess amount of unwanted nutrients and cannot be drained out without proper treatment. Such effluents are pre-treated conventionally and biologically to remove huge amount of nutrients from water. Gravitational sedimentation method itself serves to eliminate about 85 % of total suspended solids and 65 % of BOD and COD present in the waste water (Tay et al., 2006). Anaerobic treatment plays a prior role in the biological treatment due to low availability of oxygen. Aerobic treatment equips a mixed and complex group of microbes as a system.

In recent years algae have become significant organisms for biological treatment of waste water, they can accumulate plant nutrients, heavy metals, pesticides, organic and inorganic toxic substances and radioactive materials (Kalesh and Nair, 2005. Jothinayagi and Anbazhagan, 2009. Alp et al., 2011. and Alp et al., 2012). Microalgae treatment of aerobic treated waste water plays an important role in waste water treatment and supply adequate amount of oxygen through photosynthesis and of cheap cost and low man power. Microalgal treatment reduces BOD, COD, Nitrate, Ammonia and Phosphate levels etc. in treated water. And this type of biological treatment can be an efficient alternative for other energy consuming aerobic treatment.

Major objective of our study is to reduce the hardness and nutrients of fish water, to make the fish water harmless to the environment and in the reduction of fish odour. Microalgal treatment plays a vital and effective role in the reduction of high nutrient content and fish odour is well recorded.

2. Materials and methods

Fish water treatment process carried in the fishery industry itself situated around Mangalore and Goa, India. They provide us all requirements and support for performing this work. After successive treatment of fish water with anaerobes and aerobes, the treated water still has high amount dissolved nutrients which are then subjected to Primary and Microalgae treatment. In primary treatment some aerobic microbes along with microalgae were involved for the removal of nutrients in open tank at direct sunlight. In case of microalgae treatment, microalgae play a dominant role in the work. Both the primary and microalgae treatment methods were carried out in newly constructed open raceway ponds (Fig. 7). The effective microalgae consortia played in the treatment were analyzed microscopically using Compound Microscope (Olympus CH20i), photographed and identified.

Analysis of Physico-chemical parameters for raw Fish water, Anaerobic treated water, Condensated water, Aerobic treated water, Primary treated water and Microalgae treated water were analyzed by TWAD (Tamil Nadu water and drainage department lab ISO: 9001), Chennai, Tamil Nadu, India.

2.1 Physical parameters

Physical properties such as Total Dissolved Solids (TDS), Electrical conductivity (EC), Turbidity NT units, pH, Odour, Colour and Appearance were analyzed for different fish and treated water samples, results were recorded.

2.2 Chemical parameters

Chemical parameters includes Total alkalinity, Total hardness and Element analysis such as Calcium, Sodium, Potassium, Free ammonia, Nitrate, Phosphate, Tidy's test for O2, COD, BOD and TKN were analyzed for all different fish and treated water samples, results were recorded.

3. Results

Microalgae consortia involved in Primary and Microalgae treatment were analyzed microscopically and identified morphologically which are Oscillatoria sp. (Fig. 1), Chlorella vulgaris (Fig. 1) and Chroococcus sp. (Fig. 2). Physico-chemical parameters for fish and all the treated water were recorded (Table 1).

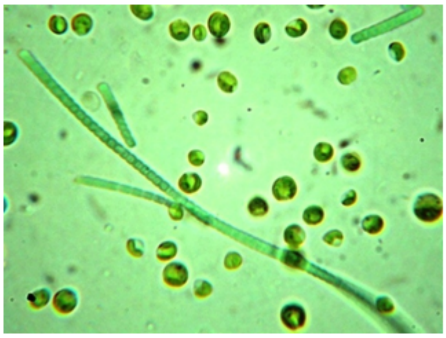

Fig. 1: Chlorella vulgaris and Oscillatoria sp.

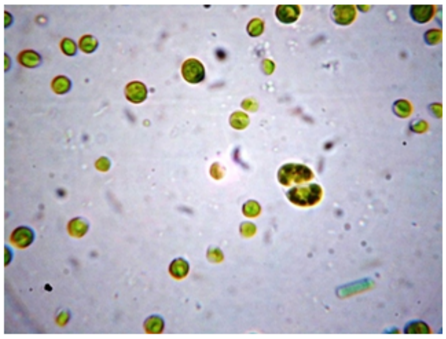

Fig. 2: Chroococcus sp.

3.1 Fish processed waste water

Fish water contains exalted amount of organic substances thus water quality is so bad, looks more turbid with fish foul odour and brown coloured. TDS (25.62 g/L) and EC (36,600 micro ohm/cm) were relatively high. Total Alkalinity (CaCO3 – 14 g/L), Total hardness of water (CaCO3 – 6.2 g/L), Calcium (Ca –c 1.840 g/L), Magnesium (Mg – 0.384 g/L), Sodium (Na – 4.3 g/L), Potassium (K – 0.9 g/L), Iron (Fe – 1.61 mg/L), Manganese (Mn - Nil), Free ammonia (NH3 – 1.008 g/L), Nitrite (NO2 – Nil), Nitrate (NO3 – 27 mg/L), Chloride (Cl – 2.750 g/L), Fluoride (F – Nil), Sulphate (SO4 – 0.763 g/L), Phosphate (PO4 – 43.32 mg/L), Oxygen Tidy's test for 4 hrs (O2 – 0.447 g/L), COD (8.294 g/L), BOD (0.660 g/L) and TKN (1.727 g/L) are shown quantitatively high when compared to other treated water (Table 1).

3.2 Anaerobic treated water

In Anaerobic treated water, parameters such as high Turbidity with 33.1 NT units comparatively higher than Fish water, TDS (19.39 g/L) and EC (27,700 micro ohm/cm) were reduced up to 25 % compared to fish water. Total alkalinity (CaCO3 - 6 g/L and 57.2 % of removal) Total hardness (CaCO3 – 1.76 g/L and 71.7 % of removal), Calcium (Ca – 0.384 g/L and 79.83 % of removal), Sodium (Na – 2.7 g/L and 37.21 % of removal), Potassium (K – 0.6 g/L and 33.34 % of removal), Free ammonia (NH3 – 0.965 g/L and 4.3 % of removal), Nitrate (NO3 – 26 mg/L and 3.70 % of removal), Phosphate (PO4 – 4.29 mg/L and 90.09 % of removal), Oxygen Tidy's test for 4 hrs (O2 – 0.349 g/L and 21.93 % of removal), COD (5.443 g/L and 34.4 % of removal), BOD (0.410 g/L and 37.88 % of removal) and TKN (1.662 g/L and 3.76 % of removal) were comparatively reduced. Parameters such as Magnesium (Mg – 1.76 g/L), Iron (Fe – 1.76 mg/L), Chloride (Cl – 3.750 g/L) and Sulphate (SO4 – 1.357 g/L) were increased compared to fish water. Manganese (Mn), Nitrite (NO2) and Fluoride (F) were absent (Table 1 and Fig. 8a to 8m)

Anaerobic treatment was carried out in closed tank to maintain anaerobism (Fig. 4).

3.3 Condensated water

Water quality looks less turbid and colourless with fishy odour. Condensated water with low turbidity having 5.6 NT units comparatively low to fish water. TDS (2.142 g/L) and EC (3060 micro ohm/cm) were reduced up to 91.7 % compared to fish water. Total alkalinity ($CaCO_3$ – 0.580 g/L) and Total hardness of water ($CaCO_3$ – 0.900 g/L) reduced up to 95.9 % and 85.5 % respectively. Calcium (Ca – 0.256 g/L and 86.08 % of removal), Magnesium (Mg – 0.062 g/L and 83.85 % of removal), Sodium (Na – 0.320 g/L and 92.56 % of removal), Potassium (K – 0.050 g/L and 94.45 % of removal), Iron (Fe – 0.67 mg/L and 58.3 % of removal), Free ammonia (NH_3 – 0.293 g/L and 70.89 % of removal), Nitrate (NO_3 – 11 mg/L and 59.25 % of removal), Chloride (Cl – 0.600 g/L and 78.18 % of removal), Sulphate (SO_4 – 0.154 g/L and 79.81 % of removal), Phosphate (PO_4 – 25.46 mg/L and 41.2 % of removal), Oxygen Tidy's test for 4 hrs (O_2 – 0.056 g/L and 87.48 % of removal), COD (0.907 g/L and 89.07 % of removal), BOD (0.120 g/L and 81.82 % of removal) and TKN (0.631 g/L and 63.43 % of removal) were reduced compared to fish water. Manganese (Mn) was absent with low amount of Nitrite (NO_2) and Fluoride (F) (Table 1 and Fig. 8a to 8m).

3.4 Aerobic treated water

In case of Aerobic treated water Turbidity was high compared to fish water with 42.8 NT units; TDS (1.638 g/L) and EC (2340 micro ohm/cm) were reduced compared to fish water both in percentage of 93.7 %. Total alkalinity ($CaCO_3$ – 0.264 g/L and 98.2 % of removal) and Total hardness of water ($CaCO_3$ – 0.550 g/L and 91.2 % of removal) were removed up to 98.2 % and 91.2 respectively. Calcium (Ca – 0.132 g/L and 92.83 % of removal), Magnesium (Mg – 0.053 g/L and 86.19 % of removal), Sodium (Na – 0.250 g/L and 94.18 % of removal), Potassium (K – 0.030 g/L and 96.66 % of removal), Iron (Fe – 1.09 mg/L and 32.29 % of removal), Nitrate (NO_3 – 24 mg/L and 11.11 % of removal), Chloride (Cl – 0.460 g/L and 83.27 % of removal), Sulphate (SO_4 – 0.130 g/L and 82.96 % of removal), Phosphate (PO_4 – 34.37 mg/L and 20.66 % of removal), Oxygen Tidy's test for 4 hrs (O_2 – 0.029 g/L and 93.57 % of removal), COD (2.221 g/L and 73.22 % of removal), BOD (0.240 g/L and 63.63 % of removal) and TKN (0.508 g/L and 70.58 % of removal) were reduced. Manganese (Mn) was absent with trace amounts of Nitrite (NO_2) and Fluoride present in it (Table 1 and Fig. 8a to 8m).

3.5 Primary treated water

Primary treated water qualitatively less turbid with 7.3 NT units and reduced in fish odour. TDS (2.338 g/L) and EC (3340 micro ohm/cm) are reduced simultaneously with 90.87 %. Total Alkalinity ($CaCO_3$ – 0.356 g/L) and Total hardness of water ($CaCO_3$ – 0.760 g/L) are also up to 97.45 and 87.74 % respectively compared to fish water. Calcium (Ca – 0.192 g/L and 89.56 % of removal), Magnesium (Mg – 0.067 g/L and 82.55 % of removal), Sodium (Na – 0.330 g/L and 92.32 % of removal), Potassium (K – 0.040 g/L and 95.55 % of removal), Iron (Fe – 0.60 mg/L and 62.73 % of removal), Free ammonia (NH_3 – 0.203 g/L and 79.86 % of removal), Nitrate (NO_3 – 12 mg/L and 55.55 % of removal), Chloride (Cl – 0.630 g/L and 77.09 % of removal), Sulphate (SO_4 – 0.242 g/L and 68.28 % of removal), Phosphate (PO_4 – 2.75 mg/L and 93.65 % of removal), Oxygen Tidy's test for 4 hrs (O_2 – 0.040 g/L and 91.05 % of removal), COD (0.778 g/L and 90.61 % of removal), BOD (0.120 g/L and 81.81 % of removal) and TKN (0.517 g/L and 70.63 % of removal) are removed biologically compared to fish water. Manganese (Mn) and Fluoride (F) are absent with trace amount of Nitrite (NO_2) (Table 1 and Fig. 8a to 8m).

3.6 Microalgae treated water

Three microalgae consortia (Chlorella vulgaris, Oscillatoria sp. and Chroococcus sp.) were involved in the microalgae treatment of fish water. As expected, high reduction of organic nutrients were seen from the treated fish water by photosynthetic microalgae (Fig. 7b). Microalgae treated fish water looks colourless and very less fish odour with low turbidity of 16.5 NT units. TDS .030 g/L and EC 1471 micro ohm/cm were reduced 96 % simultaneously. Total alkalinity ($CaCO_3$ – 0.520 g/L) and Total hardness of water ($CaCO_3$ – 0.160 g/L) were also removed up to 96 % and 98 % respectively. Calcium (Ca – 0.048 g/L and 98 % of removal), Magnesium (Mg – 0.010 g/L and 98 % of removal), Sodium (Na – 0.240 g/L and 95 % of removal), Potassium (K – 0.030 g/L and 96.66 % of removal), Iron (Fe – 0.81 mg/L and 50 % of removal), Free ammonia (NH_3 – 0.248 g/L and 75.39 % of removal), Chloride (Cl – 0.075 g/L and 98 % of removal), Sulphate (SO_4 – 0.037 g/L and 96.2 % of removal), Phosphate (PO_4 – 2.21 mg/L and 95 % of removal), Oxygen Tidy's test for 4 hrs (O_2 – 0.075 g/L and 83.22 % of removal), COD (1.555 g/L and 81.25 % of removal), BOD (0.200 g/L and 69.69 % of removal) and TKN (0.609 g/L and 64.73 % of removal) were reduced compared to fish water. Manganese (Mn) and Fluoride (F) were absent with low amount of Nitrite (NO_2) and Nitrate (NO_3) (Table 1 and Fig. 8a to 8m).

Fig. 3: Fish grinding unit in fish Processing industry

Fig. 4: Anaerobic treatment tank

Fig. 5: Fish oil storage tanks

Fig. 6: Fish powder storage area

Fig. 7: Raceway ponds with single axis rotating motor constructed for fish waste water treatment., 7a. Primary treatment, 7b. Microalgae treatment and 7c. Final treated water.

4. Discussion

Biological treatment systems can convert approximately one-third of the mixed and dissolved organic matter into stable end products. Fish processed waste water are very high in BOD, COD, Total suspended solids (TDS), fat-oil-grease (FOG), Pathogenic and other microflora, organic matters and nutrients (Islam et al., 2004). Microalgae play a vital role in the treatment of sewage waste water was already reported; in this study microalgae found to be the efficient player of nutrient removal from the aerobic treated fish waste water. Microalgae treated water resulted in the maximum nutrient removal (10 parameters) at an average of 87.94 % including all the nutrients after successive aerobic treatment (Fig. 9).

Anaerobic treatment of raw fish effluent followed by an aerobic treatment is an effective process in fish effluent treatment methods (Chowdhury et al., 2010). The advantage of anaerobic process coupled with the presence of biodegradable wastes in the effluent treatment and makes it a necessary choice for such treatment (Saleh and Mamood, 2004). Anaerobic treatment removes 25 %, 34 % and 37 % of TDS, COD and BOD respectively. Before going to the anaerobic treatment a pre-treatment step can be followed for the removal of suspended solids is essential. At the same time a post-anaerobic treatment is necessary to attain permissible COD and BOD before discharge. Anaerobic treatment was needed for high BOD and COD rich waste water treatment (Tay et al., 2006). The methane rich gas which is generated as a result of anaerobic treatment can be captured for use as a fuel (Johns, 1995). Anaerobic treatment of bio-effluents widely accepted step in removing 90 % of COD in the effluent stream and 80 – 90 % of BOD removal takes place and at the same time biochemical energy recovered is 85 – 90 % as biogas (Pant and Adholeya, 2007; Satyawali and Balakrishnan, 2008).

The best Total dissolved solids removal efficiencies were 53 % and 79 %, the aerobic biological treatment proved to be very adequate to organic matter removal. Combining physico-chemical and biological processes, proved to be an effective alternative to start the fish waste waters treatment for further reuse in industrial process (Cristovao et al., 2012). In our study, 96 % of TDS was removed in Microalgae treatment using microalgae. In raw fish effluent peaks of concentration of organic load or flow peaks can be damped in the microalgae treatment tanks (Gonzalez, 1996). In fish processing industries extended aeration type activated sludge processes are used because of higher oxygen requirement compared to other food processing units. An integrated method of anaerobic digestion followed by an aerobic treatment would yield better treatment efficiency with low energy and capital consumption and reduced sludge production (Chowdhury et al., 2010). From our investigation, a consecutive treatment of anaerobic to aerobic found to effective in organic removal from fish processed raw effluent.

Fish processing waste water contains high level of Total dissolved solids which are proteins and lipids (Palenzuela-Rollon et al., 2002). The pH from fish processed water always close to neutral and different fisheries from British Columbia found pH range of 5.7 – 7.4 with an average of 6.48. In this study, pH ranged from 7.23 to 8.16 and average pH was 7.5. BOD and COD ratios varied among fish processing plants ranging from 1.1: to 3:1 (Technical Report Series FREMP, 1994). BOD of Tuna waste was 500-1500 mg/L and COD was 1300-3250 mg/L (Carawan et al., 1979). Highest value COD was recorded 93000 mg/L from fish meal blood water (Valle and Aguilera, 1990). Percentage of COD removal ranged from 95 % to 60 % and the nitrification percentage ranged from 65 % to 20 % (Garrido et al., 1998). TKN removal was seen in Aeration and Primary treatment as 70 % of removal for both the treatment. From overall investigation, 90 % and above reduction of organic substances was achieved by a sequential treatment of fish processed waste water.

In contrast to microalgae treatment and other treatment methods, the former plays a vital and efficient role in the removal, reduction and utilization of high organic nutrients from the aerobic treated fish processed waste water. The microalgae involved in this treatment are Chlorella vulgaris, Chroococcus sp. and Oscillatoria sp., in which Oscillatoria spp. and Chlorella vulgaris are already reported in several waste water treatment especially in high protein and lipid content respectively. Presence of Chroococcus sp. in the treatment of fish processed waste water is a new report from this study, specific role played by such microalga is not known.

5. CONCLUSION

From this fish processed waste water treatment study, it was concluded that the best result was achieved in the treatment of Photosynthetic microalgae such as Oscillatoria sp., Chlorella vulgaris and Chroococcus sp. Microalgae treatment removed almost 85 % - 90 % of whole nutrients compared to all the treatment methods, ranged from 97.5 % to 75.4 % Total hardness of water and Free Ammonia respectively. Protein content in ammonia from fish processed and anaerobic treated water could be a high nutrient supplement for microalgae for their growth. Total dissolved solids (TDS) are known to be high in protein and lipids; the left out protein after anaerobic treatment can be utilized by microalgae. Elements removal such as Na, K, Tidy's test of O_2, SO_4, PO_4, NO_3, Cl, Ca and Mg was effective in Microalgae treatment 240, 30, 75, 37, 2.21, 36, 75, 48 and 10 mg/L respectively. Increasing demand of fish processed fish products globally and loading of waste water in to environment is also increasing. In order to follow the norms and regulations of government to reduce high organic waste water before drain the waste water to the environment. Phycoremediation of fish processed waste water from this investigation will be a better remedy for nutrient removal, Reduction of fish odour and make it eco-friendly.

6. Acknowledgement

We like to thank The Principal and The Head, Department of Plant Biology and Plant Biotechnology, Presidency College, Chennai, India. for providing their support. We express our thanks to TWAD, Chennai, India, for water analysis. And our sincere thanks to Fishery process Company, Mangalore and Goa, India, for providing permission and place to do our work in the industry.

Table 1. Tabular representation of Physico-chemical parameters of fish processed waste water and different stages of treated fish waste water

Sl. No.	I Physical examination	Fish processed waste water	Anaerobic treated water	Condensated water	Aerobic treated water	Primary treated water	Microalgae treated water
1	Appearance	*Turbid*	*Turbid*	*Turbid*	*Turbid*	*Turbid*	*Turbid*
2	Colour	*Brownish*	*Brownish*	*Colourless*	*Brownish*	*Colourless*	*Colourless*
3	Odour	*Stinky foul smell*	*Stinky foul smell*	*Foul smell*	*Foul smell*	*Foul smell*	*Foul smell*
4	Turbidity NT Units	26.6	33.1	**5.6**	**42.8**	7.3	16.5
5	Electrical Conductivity (EC) Micro ohm/cm	**36600**	27700	3060	2340	3340	**1471**
6	Total dissolved Solids (TDS) mg/L	**25620**	19390	2142	1638	2338	**1030**
7	pH	**7.23**	7.3	7.6	7.52	7.74	**8.16**
	II Chemical examination						
8	Ph. Alkalinity as $CaCO_3$ mg/L	0	**8000**	0	0	0	0
9	Total Alkalinity as $CaCO_3$ mg/L	**14000**	6000	580	**264**	356	520
10	Total Hardness as $CaCO_3$ mg/L	**6200**	1760	900	550	760	**160**
11	Calcium as Ca mg/L	**1840**	384	256	132	192	**48**
12	Magnesium as Mg mg/L	384	**1760**	62	53	67	**10**

13	Sodium as Na mg/L	**4300**	2700	320	250	330	**240**
14	Potassium as K mg/L	**900**	600	50	**30**	40	**30**
15	Iron as Fe mg/L	1.61	**1.76**	0.67	1.09	**0.6**	0.81
16	Manganese as Mn mg/L	0	0	0	0	0	0
17	Free Ammonia as NH_3 mg/L	**1008**	965.44	293.44	215.04	**203.84**	248.64
18	Nitrite as NO_2 mg/L	0	0	**0.02**	**3.96**	0.29	0.05
19	Nitrate as NO_3 mg/L	**27**	26	**11**	24	12	36
20	Chloride as Cl mg/L	2750	**3750**	600	460	630	**75**
21	Fluoride as F mg/L	0	0	**0.41**	**0.03**	0	0
22	Sulphate as SO_4 mg/L	763	**1357**	154	130	242	**37**
23	Phosphate as PO_4 mg/L	**43.32**	4.29	25.46	34.37	2.75	**2.21**
24	Tidy's test 4 hrs. as O_2 mg/L	**447**	349	56	**29**	40	75
25	C. O. D - mg/L	**8294**	5443	907	2221	**778**	1555
26	B. O. D - mg/L	**660**	410	**120**	240	**120**	200
27	T. K. N - mg/L	**1727**	1662.08	631.68	**508.48**	517.44	609.28
28	Chromium	0.584	**0.588**	0.038	0.023	**0.021**	0.112

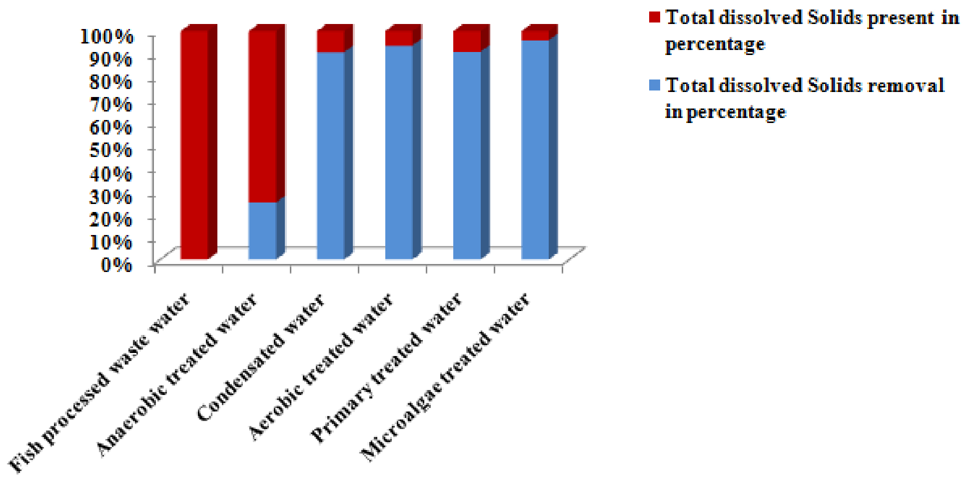

Fig. 8a: Total dissolved solids (TDS) analysis in terms of percentage comparison between different treated fish processed water

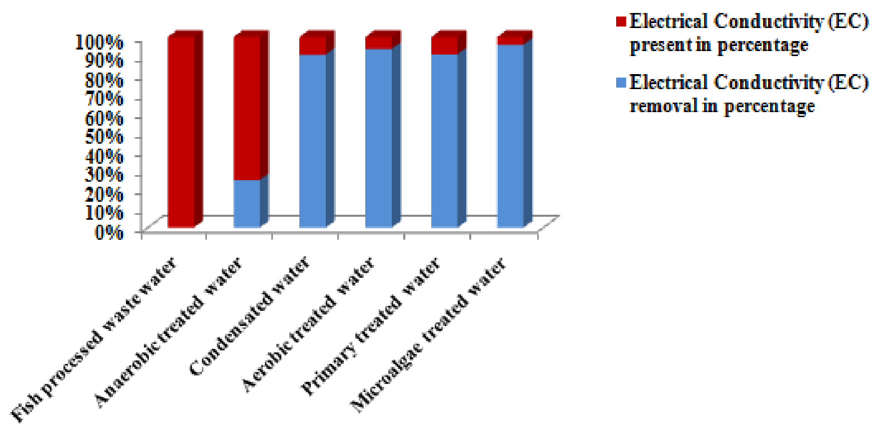

Fig. 8b: Electrical conductivity (EC) analysis in terms of percentage comparison between different treated fish processed water

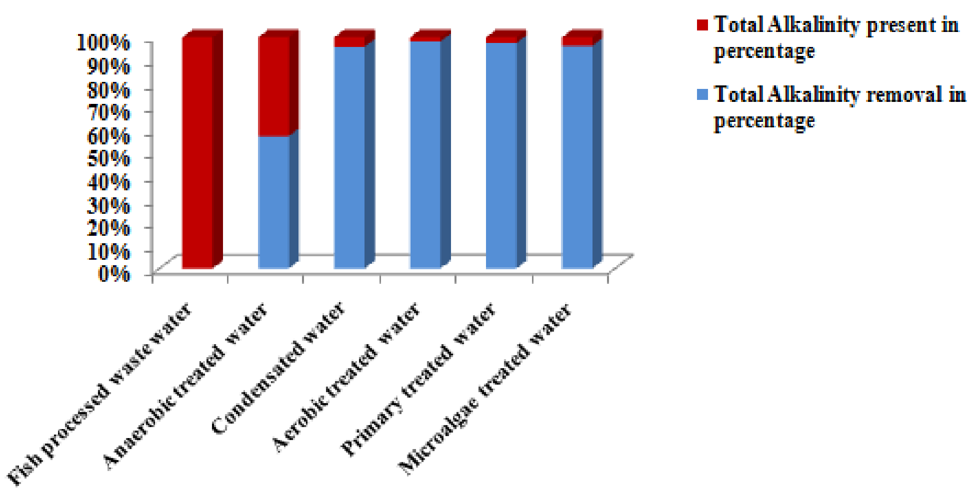

Fig. 8c: Total alkalinity analysis in terms of percentage comparison between different treated fish processed water

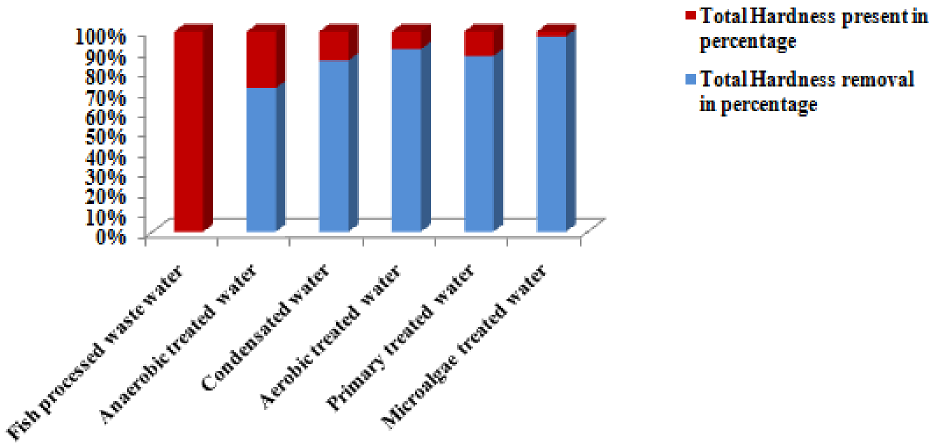

Fig. 8d: Total hardness analysis in terms of percentage comparison between different treated fish processed water

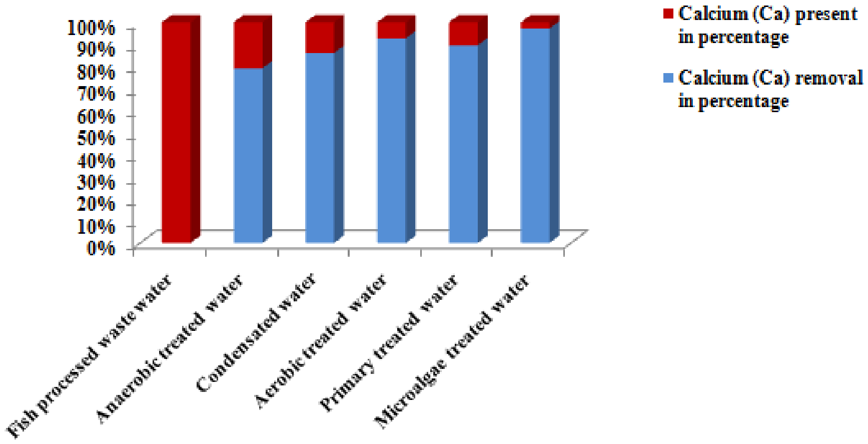

Fig. 8e: Calcium (Ca) analysis in terms of percentage comparison between different treated fish processed water

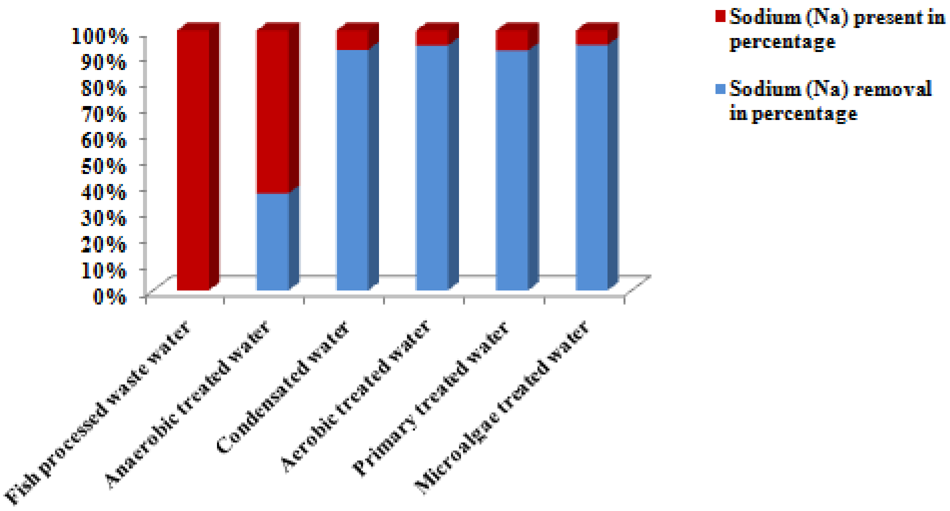

Fig. 8f: Sodium (Na) analysis in terms of percentage comparison between different treated fish processed water

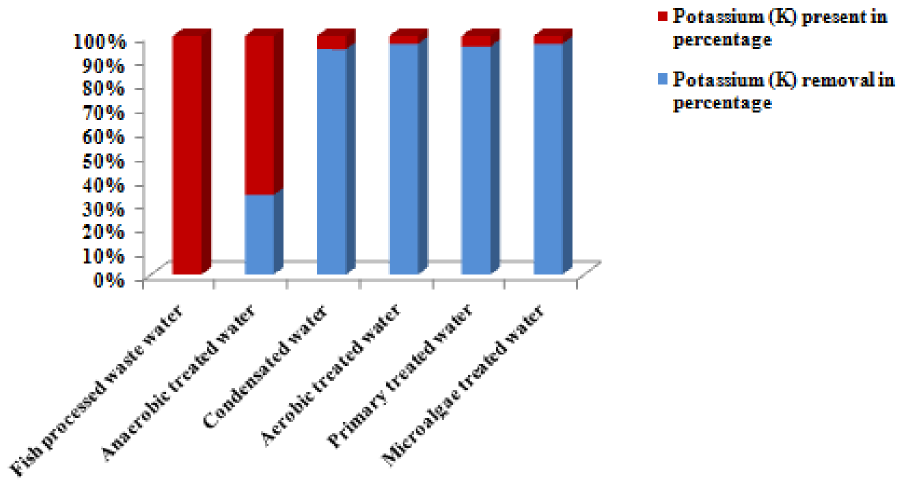

Fig. 8g: Potassium (K) analysis in terms of percentage comparison between different treated fish processed water

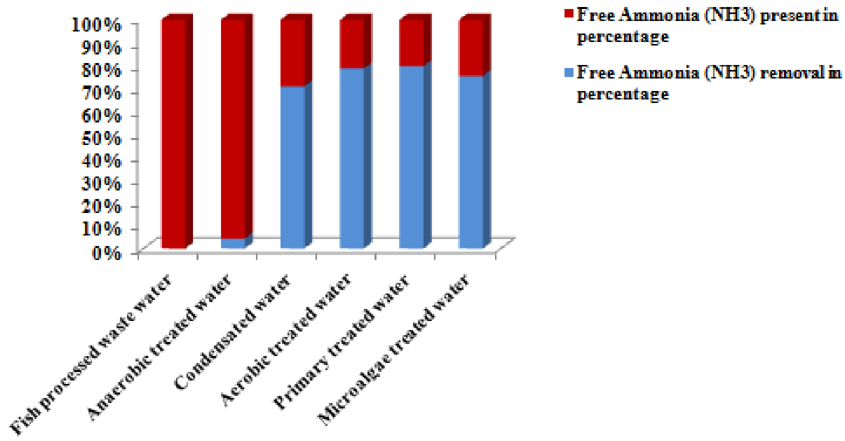

Fig. 8h: Free ammonia (NH3) analysis in terms of percentage comparison between different treated fish processed water

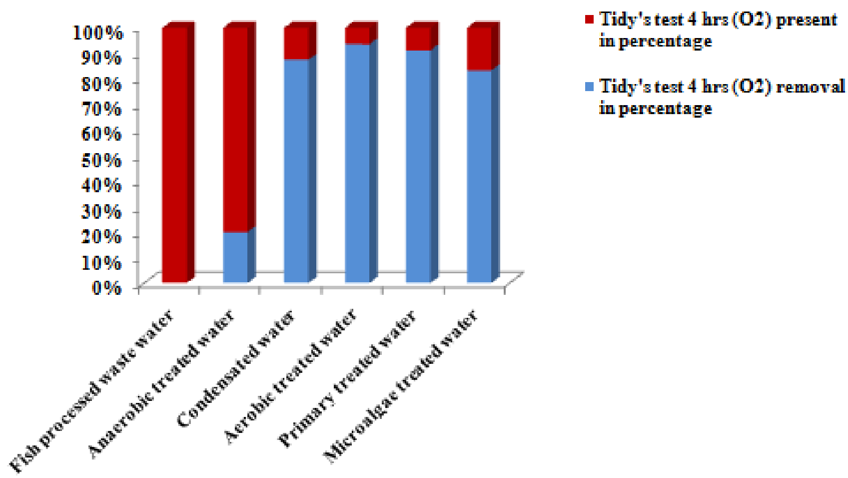

Fig. 8i: Tidy's test (4 hrs) (O_2) analysis in terms of percentage comparison between different treated fish processed water

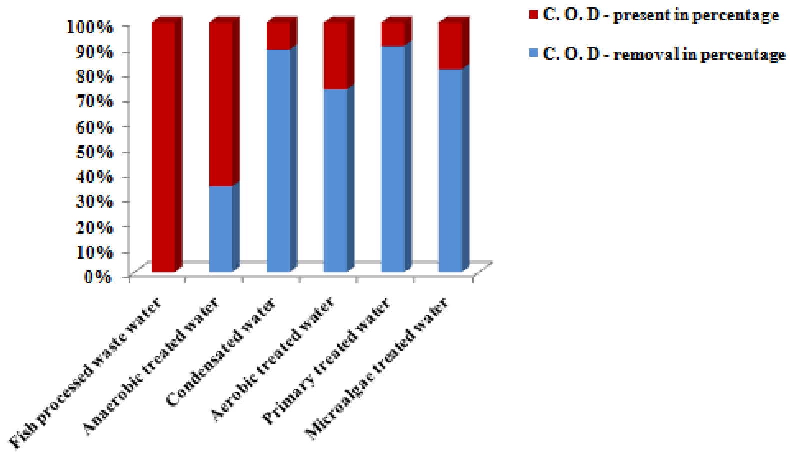

Fig. 8j: Chemical oxygen demand (COD) analysis in terms of percentage comparison between different treated fish processed water

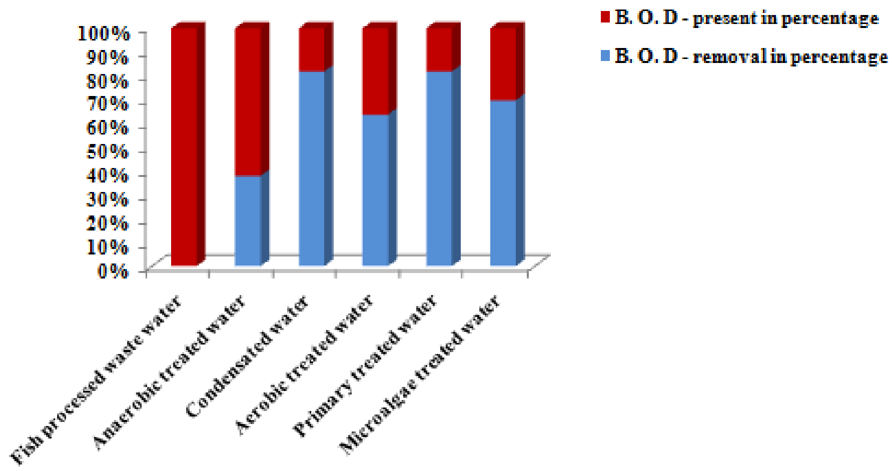

Fig. 8j: Chemical oxygen demand (COD) analysis in terms of percentage comparison between different treated fish processed water

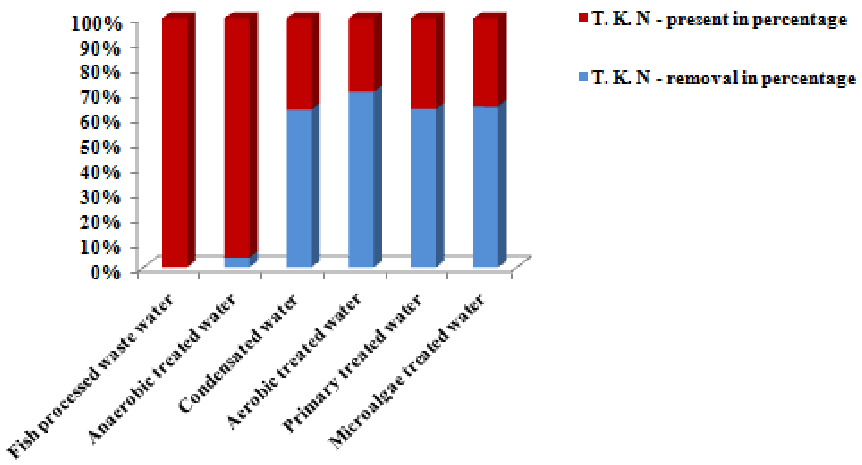

Fig. 8l: Total Kjeldahl nitrogen (TKN) analysis in terms of percentage comparison between different treated fish processed water

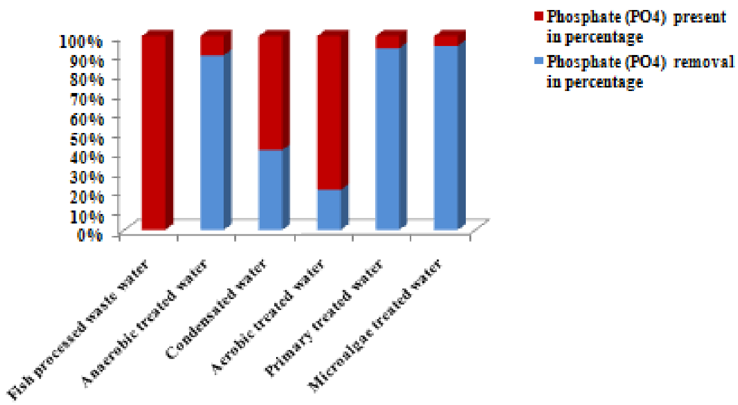

Fig. 8m: Phosphate (PO_4) analysis in terms of percentage comparison between different treated fish processed water

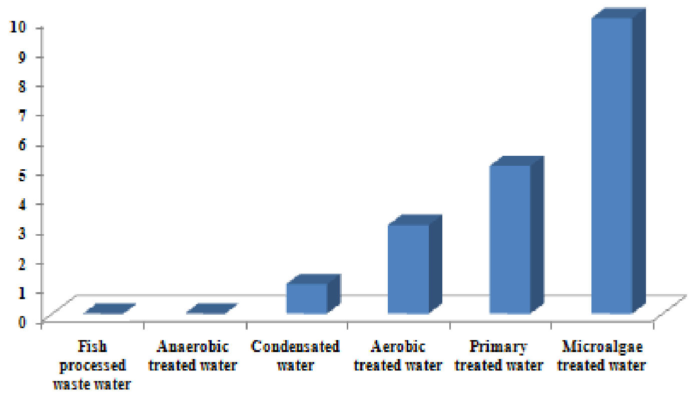

Fig. 9: Number of Physico-chemical parameters reduced as compared to different treatments of fish water

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