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Review Article

Review the Status of Resource-Efficient and Sustainable Wastewater Treatment for the Fishery Industry

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Abstract

Seafood industry resource-efficient and sustainable practice was gained prominence in current centuries. The practice of microalgae culture in seafood effluent usage has the potential to solve environmental issues, improve resources, and provide value-added goods to society and the environment. Using algal mass provides viable profits by treating seafood discharges and utilizing the algae biomass produced. Because of the high nutrient and organic matter content of wastewater, microalgae growth was controlled by light energy and carbon sources. Similarly, various physiochemical and biological methods are managed to ensure the optimally. The algae mass growth technology used in the seafood effluent industry's main target was sustainability and proper disposal of waste in the environment that allows for the preservation of the environment, citizens' value of life, and benefit of the society such as bio fertilizers, bioethanol, biopolymers, biodiesel, DHA, omega-3, dietary supplements for health animal feed, natural dyes, and cosmetics. In this way, treating seafood effluent with algae mass provides a chance to alleviate hygienic and ecological issues while obtaining inputs in a resource-efficient and sustainable manner. This review attempts to highlight exceptional elements of seafood effluent that can be used for water reuse and sustainable agronomic inputs using microalgae.

Keywords: Seafood, Resource-efficient and sustainable, Wastewater treatment, Algal mass

Introduction

The United Nations Food and Agriculture Organization recognize the seafood sectors for their critical role in worldwide food availability and intake of humans [32]. Collection, management, unloading, separating, balancing, slaying, cutting, and grazing are among the most important process processes in seafood production. Seafood process ranges from traditional operation to large-scale operations [16,98]. Effluent from the seafood processing sector is a serious ecofriendly concern since it contains a variety of contaminants such as organic debris, elements, oils, lubricant, and extracts made from chemicals. Moreover, heavy elements and other hazardous chemicals can gather in seafood such as finfish and shellfish, causing health hazards when consumed [87,52,53,54].

Wastewater treatment removes pollutants, particles, toxicants, and pathogens, leaving clean water (effluent) that can be settled into the environs for various authors determined [3,25,45,107].

To lower the level of contamination, numerous strategies for treating fish processing effluents can be applied. Numerous studies have described that the main method of treatment was such as sedimentation, coagulation-flocculation [21,23,24,37] chemical and biological processes [23,25,48,112]. Because of expanding population and rapid industrialization, evolving countries such as India generate massive amounts of wastewater daily. As a result, water contamination is one of the most serious environmental concerns [116].

In India, numerous conventional methods for wastewater treatment are employed, but they are prohibitively expensive and inefficient. Nowadays, various innovative resource-efficient and sustainable ways of treating seafood effluent are presented to address issues with old approaches. Biological wastewater treatment systems using microalgae have culture in over the last 50 years, and it is now generally recognized that microalga-based seafood effluent treatment methods are as operative as standard seafood effluent treatment [1,74,108].

An absence of proper seafood effluent treatment, combined with less water management, causes a deficit of hygienic water resources. This has resulted in the development in recent periods of several technical methods aimed at recovering resources from seafood effluent [55,77]. The use of biological methods has grown in new centuries, with an emphasis on the viability of connecting and using methods for seafood effluent in systems.

The Seafood Industry

The seafood sector provides consumers with their preferred finfish and shellfish through both farmed and catch fisheries. According to FAO 2020, Ahmed and Thompson, 2019 about 80% of the entire harvest is handled by the business into a variation of goods, such as foods that are freezing, burned, dehydrated, inflamed, soaked, and cooled. Venugopal, 2006 also discussed about standard quality of fish and fisheries products in foreign marketplaces. Figure 1 show the effluent generation during seafood processing.

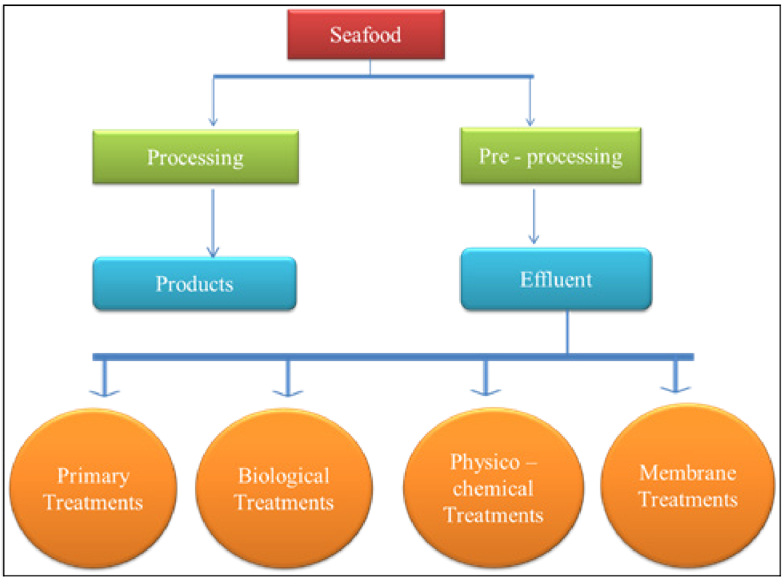

Figure 1: Effluent generation during seafood processing

According to *Weichselbaum, et al.* (2013), shrimp culture and fisheries both show roles in expanding the obtainability of seafood for dietary and fitness benefits. Fish refrigeration, canning, and fishmeal processing are the three primary categories of fish processing activities [12,104,78]. Seafood wastes decay faster than urban wastes since they contain more proteins and elements. The seafood wastes typically comprise 59% proteins, 20% fat, and 30% ash [48,7].

Numerous pre-processing procedures, including washing, decapitation, skinning, scaling, flaking, boiling, and glazing, require water. Freezing systems are also necessary to combat the consumable nature of harvested seafood at different handling phases. The transportation and storage of both raw and finished goods also require water [7,59,63,94,105].

Significant amounts of organic matter, such as solids waste, as well as extra nutrients (phosphorus and nitrogen), can be found in the effluents of processing plants [63]. Waste streams and other discards from seafood processing are full of valuable substances that may find use in the food, medical, and related trades. In adding to protective the environs, valuing seafood waste can play a major role in protecting marine resources and lowering product growth costs. Seafood effluent must be recognized as resources of different components of sustainable resources [4] (Figure 1).

Effluent Treatment

Physical, chemical, or biological methods can be used to treat wastewater at three different levels [18,38,40,109]. The primary stage was may interfere settleable materials with later processes. The secondary stage is when dissolved organic matter is consumed and the primary nutrients are oxidized to nitrate and orthophosphate by a mixture of physical and/or biological methods. The tertiary stage includes a sophisticated treatment that gets rid of trace organic chemicals, phosphates, and nitrates [118]. According to *Qin, et al.* (2023), nitrogen is typically extracted without recycling, turning it into N2 that will enter the atmosphere.

The method of precipitating phosphorus mostly includes the addition of cations such as calcium, iron, and aluminum, which is costly [19]. Phosphorus and nitrogen are used for microalgae. This natural process may appear straightforward, but it involves several intricate metabolic methods that change depending on the crop surroundings and the type of effluent that needs to be conserved [27]. Table 1 shows the estimated volumes of seafood effluent processing operations.

To effectively separate organic matter, membrane-based separation procedures, or MBSPs, have become innovative methods. Additionally, toxic elements and organisms can be eliminated from biological wastes by MBSPs [42,89]. With the potential to be recycled as a microalgae treatment in seafood effluents decrease the organic matter and other elements [5]. Algae masses have been used extensively in seafood effluent treatment because of their high tolerance to the compounds they contain. As a result, algae mass technology has gained consideration recently for the management of industrial, agro-industrial, metropolitan, and residential wastewater [91] (Table1).

Table 1: Approximate volumes of wastewater generated by seafood processing operations.

Process	Wastewater volume (m3)	References
Shrimp boiling water	12-Nov	(*Forghani, et al.*, 2020)
Salmon heads	15-17	(*Routray, et al.*, 2019)
White fish filleting	05-Nov	(*Matcon, et al.*, 2000)
Oily fish filleting	05-Aug	(*Matcon, et al.*, 2000)
Grading	0.3-0.4	(*Arvanitoyannis, and Kassaveti*, 2008)
Handling and storage of fish	12-Oct	(*Arvanitoyannis, and Kassaveti*, 2008)
fish canning wastewater	Oct-15	(*Corral, A.* 2018)
Saline Wastewater	0.2-0.9	(*Ching, Y.C.; Redzwan, G*, 2017)
Marine finfish	14	(*Arvanitoyannis, and Kassaveti*, 2008
Skinning of knobbed fish	17	(*Matcon, et al.*, 2000)
Unloading fish for canning	03-Feb	(*Corral, A.* 2018)
Precooking of fish to be canned	0.07-0.27	(*Arvanitoyannis, and Kassaveti*, 2008
Canning of sardine	15-Sep	(*Matcon, et al.*, 2000)
Sterilization of cans	06-Apr	(*Ching, Y.C.; Redzwan*, G, 2017)
Frozen fish thawing	5	(*Arvanitoyannis, and Kassaveti*, 2008
Filleting of un-gutted oily fish	01-Feb	(*Matcon, et al.*, 2000)
Processing of tuna	3	(*Fluence*, 2019)
Shrimp freezing	7	(*Arvanitoyannis, and Kassaveti*, 2008)
Blue crab, mechanized plant	29-44	(*Arvanitoyannis, and Kassaveti*, 2008
Squid cooking	12-Oct	(*Rosas-Romero, et al.*, 2010)
Fish Processing Plant	06-Apr	*Miroslav Colic, et al.*, 2007.

Physiochemical Parameters of Wastewater Treatment

The industry of seafood processing causes significant amounts of organic contamination and higher salinity in getting water. Important pollutant factors of seafood effluents include chemicals and physical parameters. Solid waste may also be present in some amounts in the effluents. As per Islam et al. (2004) and Tukker and Jansen (2006), the industry consistently disposes of massive quantities of dense waste, with by-catch, around the adjacent property.

The gases produced when the waste decomposes pollute and change the ecosystems of the receiving water bodies and lower the DO content. Furthermore, high concentrations of physiochemical parameters might be harmful to aquatic life and the environs [6,10,49]. The two most essential nutrients for the culture of microalgae are phosphorus and nitrogen. Algae absorb phosphorus as inorganic orthophosphate, another macronutrient necessary for growth [1,50].

The pH of the wastewater may also have an influence on the pace of microalgae culture and effluent treatment. The pH controls the species of inorganic carbon that are available, [14,36,41,50,65,99]. Temperature has little influence when light is limited and is proportionate to the amount of sunlight available. A temperature rise can speed up photosynthesis when light availability is not a limiting factor, which leads to faster growth and doubling rates [61].

The most accurate metric for determining the level of water contamination is BOD. The occurrence of more organic material in the effluent may be the cause of the high BOD value [67]. Because the fish processing industry uses salt to preserve sustenance, the amount of chloride in settled water has grown [114]. The presence of a significant amount of organic material in the treated wastewater may be the cause of the COD readings. This suggests that a significant number of biologically resistant chemicals are present in the organic matter of wastewater processing. Various researchers have noted similar outcomes [33,67].

Microalgae Application with Effluent Treatment

A commercial and adaptable system of concentrating and converting resources from waste or seafood effluent was useful methods is through biotechnological processes [9,20,79,84]. Biomass is processed sustainably to produce a variety of [28]. According to *Subhadra and Grinson-George* [96], algae-based biotechnology is a viable way to use waste from the food sector, including aquaculture effluents. Figure 2 shows the sustainable wastewater treatment for the fishery industry.

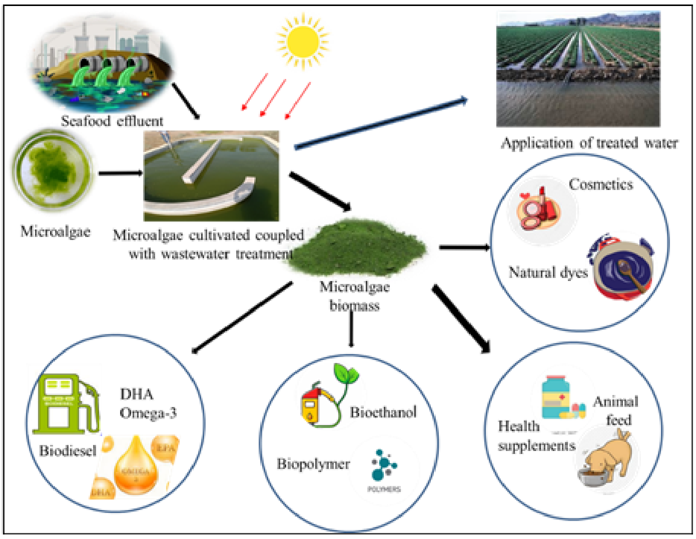

Figure 2: Sustainable wastewater treatments for fishery industry.

According to *Nagarajan, et al.* [72] and *Zhuang, et al.* [120], algae mass can improve the ecological implications of the seafood effluent treatment systems now in use by efficiently using microalgae biomass cultivated outdoors. According to Shahid et al. (2020), algae growing in seafood effluent provided the fastest biomass manufacture and the highest rate of atmospheric carbon fixation, with nearly total pollution clearance.

To treat wastewater, the strain must be able to remove a lot of nutrients and withstand high concentrations of pollutants like ammonia. While various species can absorb contaminating nutrients to varying degrees, it is important to determine the goal because we may have strains that are highly effective at treating wastewater but uninteresting in producing value-added products. To effectively integrate seafood effluent treatment with the creation of an algae mass bioproduct of profitable significance, it is crucial to ascertain yields and productivity beforehand [100]. Table 2 shows the microalgae in diverse types of wastewater treatment.

Table 2: Microalgae in different types of wastewater treatment.

Microalga	Wastewater type	References
Chlorella vulgaris	Domestic (without any pretreatment)	*Moondra, et al.*-(2020)
Chlorella variabilis	Domestic	*Tran, et al.* (2021)
Chlorella pyrenoidosa	Domestic	*Dahmani, et al.* (2016)
Muriellopsis sp.	Centrate from the anaerobic digestion of activated sludge produced during wastewater treatment	*Morales-Amaral, et al.* (2015)
Chlorella sorokiniana	Municipal wastewater	*Kotoula, et al.* -2020
Mixed of Chlorella sp and Dunaliellatertiolecta	Municipal	*Lima, et al.* (2020)
Chlorella vulgaris	Agro-industrial	*Bhuyar, et al.* (2021)
Chlorella sp	Cultivation of microalgae	*Venugopal, V.*, 2021
H. pluvialis	Cultivation of microalga	*Sahu, et al.*, 2016
Chlorella	cultivated microalgae	*Masojídek &Torzillo*, 2008
Chlorella vulgaris	cultivated microalgae	*Wang, et al.*, 2015

Microalgae Products

According to Stengel and Connan (2015), microalgae are used in a variety of diet, drug, fishery, ornamental, and green industries due to their unique development, and sustainability of sources. Studies that aim to combine sustainable practices with productive processes where the use of seafood effluents is a topic of attention can only show whether the finished product is hygienic enough to be used [66].

Biofertilizers

Due to its high nutritional content, wastewater from fish processing offers a great deal of possible use in cultivation [16]. Because of their phytochemical makeup, microalgae-based biofertilizers make macro and micronutrients available [60]. Which have a bio-stimulating impact on crops whether useful directly to crops or as compost [39,44,90]. Increase topsoil permeability [73], enhance water maintenance [70,71] enhance the yield and quality of farming products, and considerably reduce the harmfulness of plants in the topsoil [43,58,90,110].

Biogas

Anaerobic digestion can convert wastewater treatment sludge into methane [8]. Because microalgae produce a lot of biomasses that is rich in nutrition which may be used as a fresh material to manufacture bioethanol, lipid biodiesel, hydrogen through electrocoagulation, and methane through anaerobic digestion, they have a lot of promise for producing biofuels. Large-scale production is not possible because of the comparatively high costs of drying and extracting lipids and carbohydrates [75,80,97].

Pigment From Agro-Industrial Waste

Agro-industrial leftovers can produce biomass, are higher in natural stains and biomolecules, pose no chemical risk, and may be accessible on a wide scale [30,82], [17], [111]. Many beneficial compounds can be found in microalgae. According to [119], [57], [64], [103], Koutra et al. (2021), these organisms possess metabolic pathways that metabolites can be utilized in the biochemical, diet, drug, agricultural, and eco-friendly industries (Figure 2).

Fish Feed

Nutrition can be recovered from effluent treatment by disintegrating, alkalizing, ultrasonic, precipitating, and drying. The feed could be employed as good quality and assurance with nutritive diets [47,117]. Seafood effluent algae biomass may be converted into nutritional feed for fish [115]. The algal mass was potentials safe and nutritive food in the animal feed, and bio products [15,93].

Future Challenges Protective and Sustainability of Wastewater Treatment

Many national and international regulatory bodies have focused their attention on worldwide concerns over seafood-related environmental contamination [76,46]. These bodies urge that effluents be treated appropriately so that they can be discharged safely without posing unnecessary environmental risks. As a result, regulatory bodies have issued instructions and restrictions to mitigate the ecofriendly effects of commercial fish processing. The culture of algae mass for seafood effluent involves specific issues that must be researched and addressed once effective methods are available.

i. The proper plan of the bioreactor, as well as the pattern, plays an important role in the biomass production in the seafood effluent method.

ii. The proper resource-efficient and sustainable wastewater treatment for fishery industry investigations must be monitored regularly and systematically in the system.

iii. Recognize unique techniques for the culture of algal mass production systems, particularly association research with mixes of microorganisms in resource-efficient and sustainable wastewater treatment.

iv. To increase the effectiveness of photo bioreactors, combine dual-mass collecting methods with the reuse of alga media that will support resource-efficient and sustainable wastewater treatment.

v. Conduct further life cycle and planetary assessments using microalgae or consortia, and compare the results to standard wastewater management and treatment technologies.

vi. Automation technology advances, allowing for distant and effective processes. As a result, combining the effluent treatment idea with the Microalga bio refinery could open up significant prospects for resource sustainability. Pollutants dissolved in wastewater will always be converted, contributing to environmental improvement.

Conclusion

The seafood effluent treatment of microalgae has commercial and eco-friendly benefits for the environment and society. Using it can deliver effective and low-cost management in which polluting chemical elements can be removed in large quantities. Microalgae's capacity to biofix CO2 helps to reduce greenhouse gas emissions while maintaining a carbon footprint. The variety of its substance and metabolic energy confers environmental and agro-industrial benefits. The use of microalgae in agriculture has received consideration in recent centuries, as algae biomass has exposed important results in the agriculture and seafood industry. This also delivers economic benefits by producing yields with additional value from biomass that have a wide range of applications, providing the method for a resource-efficient and sustainable system. Despite this, there are tasks in the microalgae method that must be modified, such as the plan of devices or production systems, controlling of organic waste, primary and secondary control variables, and algae mass collecting, among others, so that it is essential to carry on with investigation and trying on large production, in addition to enduring to increase awareness of the culture and use of algae mass.

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Conflict of Interest

None.

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