Full Paper of the WasteSafe 2025 – 9th International Conference on Sustainable Solutions for Waste Management in Developing Countries
22-23 February 2025, Dhaka, Bangladesh

ENVIRONMENTAL RISKS, TREATMENT, AND RESOURCE RECOVERY FROM EFFLUENTS OF SEAFOOD INDUSTRIES OF KHULNA REGION

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ABSTRACT

The Khulna-Bagerhat region of Bangladesh is well known for its seafood processing industry, particularly for shrimp and fish exports. As of recent reports, Khulna is home to around 50-60 seafood processing plants, with Bagerhat also contributing to the industry. The seafood industry including aquaculture routinely uses a large amount of fresh water and discharges large volumes of post-process wastewater as effluents. Since the effluents contain proteins, oil, carotenoids, minerals, and other substances, they have a high biological and chemical oxygen demand and are a major source of environmental risks. Effluents must therefore be properly treated before being released or disposed of to reduce environmental issues. Proper treatments result in the recovery of valuable ingredients, conservation of water, environmental protection, and also production of biofuel. This study evaluates the surrounding environmental conditions, surface water quality contamination with this effluent, and the possible treatment of wastewater in a cost-effective technology, and also finds out the beneficial use of this waste of seafood industries around the Khulna region. Four seafood industries were visited. Water samples from six different locations were collected and analyzed for this study. The findings showed that the physio-chemical parameters of water pH (8.67), EC (17.68 µScm-1), and DO (1.17 mgL-1) violate the Environment Conservation Rules, 2023. Effluents with low DO often have high organic matter content, which increases the biological oxygen demand (BOD) in receiving waters. When discharged, these effluents deplete the DO in natural water bodies, which is crucial for the survival of aquatic organisms. The mean TDS also exceeded the maximum permissible level. A comprehensive plan for resource recovery from those wastes can be developed. The government, planners, academics, and industrial authorities should take the initiative with this effluent problem to resolve challenges and ensure shrimp export revenues of Bangladesh are sustainable with suitable environmental conditions.
Keywords: seafood processing industry, wastewater treatment, environmental protection, aquatic organisms, beneficial use

INTRODUCTION

The Southern region of Bangladesh, which includes the cities of Khulna, Satkhira, and Bagerhat, has become a center for the seafood sector. This area contributes significantly to the national economy through aquaculture and seafood processing due to its advantageous location close to the Sundarbans and easy access to a wealth of water resources. Millions of people's livelihoods are supported by Khulna's fish sector, which also helps the nation's export earnings. Khulna's seafood processing industries deal with a variety of fish and seafood species. These species are processed primarily for export. Shrimps, however, are the primary species. Shrimp is known as the “White gold of Bangladesh”. Most of the fish and shrimp processing plants of Bangladesh are located in Khulna (56 out of 100) and Chittagong (38 out of 100) regions (Md Jakiul Islam, 2021). Among the 11 shrimp species in Bangladesh, four species are common and worth mentioning *Macrobrachium rosenbergii* (the golda), *Metapenaeus monoceros* (the harina), *Penaeus indicus* (the chaka), and *Penaeus monodon* (the bagda) (Sk. Shafiqur Rahman, 2010). Shrimp are processed and packaged for export to the global market by these industries. Exports of frozen shrimp fell from 39,706 tons in the fiscal year 2016–17 to 36,168 tons in the fiscal year 2017–18. The most recent statistics from the Bangladesh Frozen Foods Exporters Association show that exports dropped to 33,306 tons in 2018–19 and 30,036 tons in 2019–20. In the fiscal year 2021–2022, the amount of shrimp produced dropped to 30, 571 tons. Several factors have contributed to this decline in shrimp production and exports from Khulna:

- Environmental Challenges: Drought conditions and higher temperatures have led to increased shrimp mortalities and disease outbreaks.
- Market Dynamics: Global demand fluctuations and price reductions have impacted the profitability of shrimp farming.
- Production Issues: Farmers face challenges such as scarcity of quality shrimp fry, poor farm management, and disease outbreaks like white spot disease and Acute Hepatopancreatic Necrosis Disease (AHPND).

Despite these challenges, the Khulna region remains a central player in Bangladesh's shrimp industry, with ongoing efforts to address these issues and revitalize production. In the Khulna region, 90% of the shrimp produced are exported, with the remaining 10% being consumed locally. However, according to the data from the Export Promotion Bureau (EPB), in the last six months of the FY 2021-2022 (July- December), earnings from shrimp export stood at USD 268.96 million, a significant jump from USD 194.58 million registered in the same period last year. Figure 1 shows the earnings from export (in Million USD) & the percentage of exported shrimp to different parts of the world.

These industries generate a significant amount of solid waste and effluents, which are then dumped in local water bodies, rivers, canals, low-lying areas, roadside ditches, and agricultural lands. Every day, plant operations produce an unknown amount of wastewater and roughly 35% of the weight of waste heads and other solid trash. Fish processing activities involve the production of large quantities of biodegradable solid organic wastes and by-products from inedible fish parts as well as effluents containing salts, fat-oil-grease (FOG), proteins, carbohydrates, suspended and dissolved solids, high levels of phosphates and nitrates, heavy metals and pathogenic and other microflora (G. Vallini, 1989) . Transportation, processing, quality control, and packaging are all involved in fish processing. Workers at the processing facility will clean, devein, remove the heads, and package the shrimp in boxes lined with plastic. Before being loaded and shipped on refrigerated trucks, the shrimp will be blast frozen (-40°C) and refrigerated (-20°C). In the shrimp processing industry, shrimp are processed using various machinery. Compressors, flake ice machines, chill water machines, generators, plate freezers, blast freezers, boilers, cold freezers, ice stores, ice-breaking machines, air coolers, reverse osmosis plants, ozone generators to eliminate bacteria, UV treatment plants, individual quick frozen machines (IQF machines), metal detectors, shrink wrapping machines, soaking machines, water pump commercial cook machines, etc. are among the most common pieces of machinery. These machines are responsible for the generation of heat, noise, and foul odor which creates public nuisance and is problematic for health (Basanta K. Barmon, 2011) . Environmental Impact Assessment (EIA) of the wastes and effluents released from the fish processing industries confirmed potential negative impacts on soil physical and chemical properties and water quality around the industries (Billah, 2016).

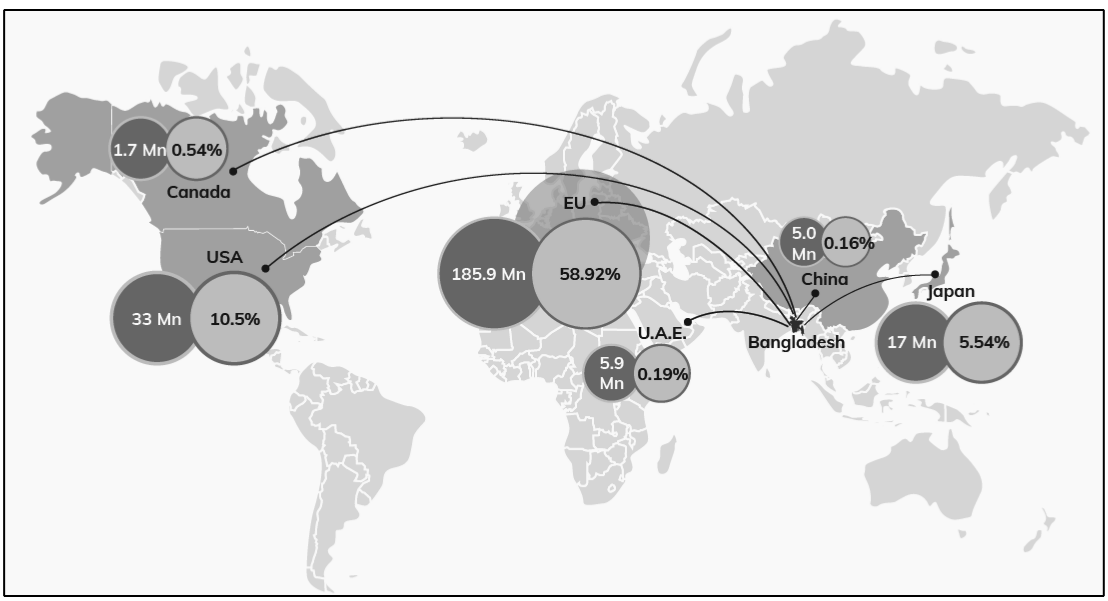

Figure 1 Bangladesh Export Destinations (FY 2020-2021) (Source: EPB)

Shrimp processing industries generate significant amounts of waste, both solid and liquid, which, if not managed properly, can pose environmental risks. The complex mixtures of various substances, such as fish and shrimp muscles, scales and shells, soluble proteins, fats and oils, partially decomposed organic

ISBN: 978-984-35-7297-4

matter, various chemicals, pathogens, bacteria, viruses, and other microflora, as well as inorganic nutrients, especially nitrogen, and phosphorus, are among the many substances that are produced by shrimp processing plants. The majority of the waste that is produced is released into the adjacent river via discharge channels, which may pose a risk to the habitats that receive it. 70% of the depots dumped their waste materials to the nearest pond/ditch and the remaining 30% of depots dumped their waste near the drain. 100% of agents of Bagerhat district didn't treat their waste material before dumping and 40% of agents dumped near ponds/ditches/canals whereas 60% of agents sold their waste materials. The owners of the shrimp processing plants said that they sold their 60% shrimp waste including shrimp heads, and shrimp shells while 40% of waste materials were dumped near ponds/ditches (Sk. Shafiqur Rahman, 2010). The Environment Conservation Rules, 2023, state that the standards for the discharge or emission of wastes from different industrial units must be determined following Schedule -12, while the standard limits for the discharge of liquid waste and gaseous emission must be determined per Schedules 9, 10, and 11. However, the study makes it clear that the Khulna region's shrimp processing companies are releasing massive volumes of wastewater without installing ETP. Even though certain sectors have wastewater treatment facilities, none of them was working properly. The specific objectives of this study are outlined as to investigate the surrounding environment and nearby surface water contamination with this effluent, to suggest a more effective strategy for the possible treatment of wastewater in a cost-effective technology, and also to find out the beneficial use of these waste of seafood industries around Khulna region.

MATERIALS AND METHODS

The Khulna region, located in southwestern Bangladesh, is a diverse geographical area characterized by its proximity to the Bay of Bengal and its location within the deltaic plain formed by the Ganges, Brahmaputra, and Meghna rivers. The approximate latitude and longitude of Khulna, Bangladesh, are 22°50' N and 89°32' E. Mostly low-lying, with heights between 1 and 5 meters above sea level, it is susceptible to flooding and tidal surges. The region is crisscrossed by numerous rivers, including the Rupsha, Bhairab, and Passur, which provide a system of irrigation and natural transportation routes. A tropical monsoon climate, with hot, humid summers, heavy monsoons, and mild winters. A mix of clayey and loamy soils, with saline intrusion affects agricultural potential in coastal zones.

There is a surface water treatment plant in Khulna, named Bangabandhu Water Treatment Plant (BWTP). The BWTP had gained 70PIs among 80PIs. This result was satisfactory to consumers. Though some pathogens were found in treated and supplied water, the removal efficiencies of other units were quite good (Debanjon Shome, 2024). However, there is no central Waste Water Treatment Plant (WWTP) in Khulna. One WWTP is under construction under Khulna WASA's Khulna Sewerage System Development Project, which will go into production around the middle part of 2026.

Approximately 60 percent of Bangladesh's registered shrimp processing industries are located in this area. Here are some Seafood Product Processing and Packaging Industries in Khulna, Bangladesh: Fresh Foods Limited, Modern Sea Food Industries Limited, Sobi Fish Processing Industries Limited, Southern Foods Limited, Crimson Rosella Sea Food Limited, Rosemco Foods Limited, Organic Shrimps Export Limited, Jahanabad Sea Foods Limited, Khulna Frozen Foods Export Limited, National Sea Food Industries Limited, Atlas Sea Food Limited, Bionic Sea Food Exports Limited, Rupsha Fish & Allied Industries Limited, Rupali Sea Foods Limited, Chalna Marine Products Limited, Trust Seafood Industries Limited, Jahanabad Sea Foods Limited, Modern Seafood Industries Limited, Total Seafood Industries Limited etc. Four industries were visited during the survey session. Figure 2 illustrates the location of these factories. The names are not listed here due to privacy concerns. All four industries are located in Rupsha Upazilla, Khulna, Bangladesh. As the concentration of the seafood industry is high here, that's why this area was chosen.

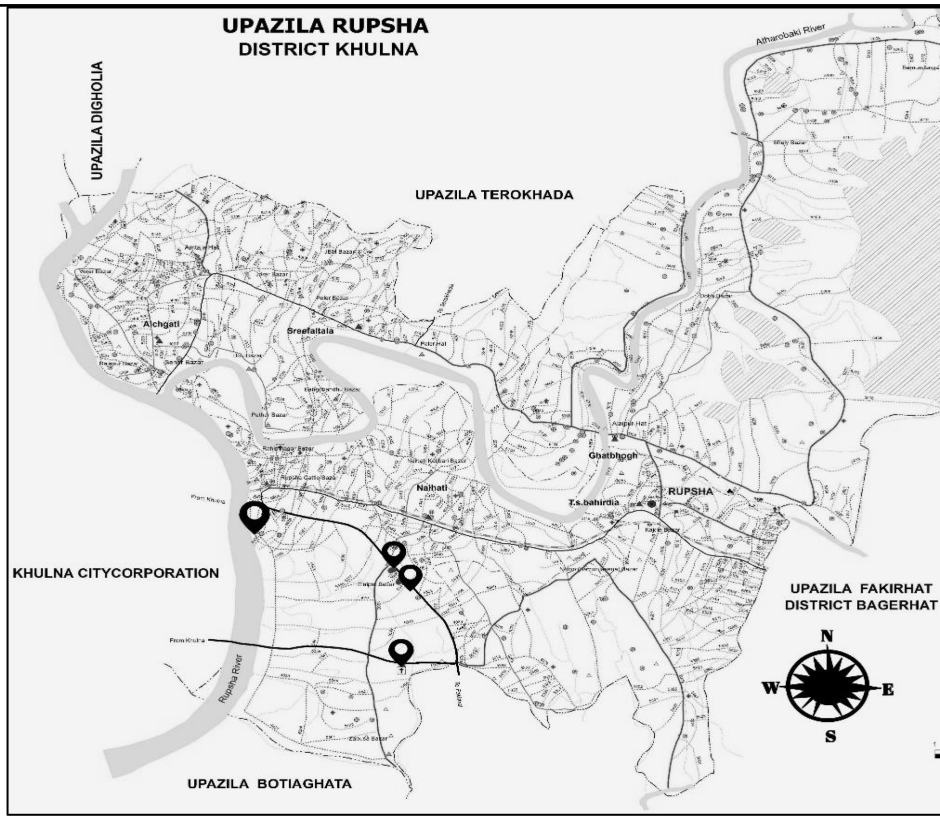

Figure 2 Location of the Surveyed Seafood Industries of Rupsha Upazila

Wastewater and soil samples were collected from three different locations in each industry. Point 1 was the primary location for the discharge of wastewater and the disposal of waste; Point 2 was the location where highly polluted wastewater accumulated; and Point 3 was the location of the contaminated agricultural land. Samples were collected during the peak time for processing. Seasonal variation was not taken into account. A clean plastic container was used to collect the samples, which were then thoroughly cleaned with non-ionic detergent, rinsed with tap water, and then cleaned with deionized water before being used.

Analytical Methods:

The following physical, chemical, and Microbiological parameters were analyzed in wastewater samples.

Physicochemical Analysis: Parameters analyzed (e.g., pH, Turbidity, Color, TDS, TSS, EC, Hardness, BOD, COD, Nitrate (NO_3^-) and Chloride.

Microbiological Analysis: Methods for identifying microbial contamination (e.g., Fecal Coliforms and Total Coliforms pathogen detection).

Treatment Techniques

There are different techniques for the treatment of wastewater. When an effluent of an industry is going to be discharged into a natural stream, before discharging, it should be treated according to the standards of that area's environmental agencies. In the context of Bangladesh, ECR-2023 has set a standard for discharging effluent for the industries. There are several factors to take into consideration while designing an effluent treatment plant (ETP) for the seafood processing industries, such as the type of wastewater generated, regulatory requirements, environmental hazards, and resource recovery. Table 1 suggests (Cornwell) different units that should be included and which should be subtracted in wastewater treatment plants based on the raw water's quality.

Table 1 Recommended Treatment Methods (Cornwell)

Parameter	Treatment Process
Floating matter	Coarse screens, fine screens
Suspended matter	Microscreens
Algae	Microscreens, pre-chlorination, carbon adsorption, rapid filtration
Turbidity	Coagulation, sedimentation, post-chlorination
Color	Flocculation, coagulation, filtration
Taste and odour	Activated carbon
Hardness	Coagulation, filtration, lime softening
Iron and manganese	
> 1 mg/L	Pre-chlorination
< 1 mg/L	Aeration, coagulation, filtration
Pathogens	
MPN/100mL	Post-chlorination
<20	Coagulation/filtration/post-chlorination
20-100	Pre-chlorination/Coagulation/filtration/post-chlorination
>100	
Free Ammonia	Post-chlorination, Adsorption

It is possible to recover resources from the seafood industry's effluent. Effluents from seafood processing are enriched with organic materials, nutrients, and other chemicals that can be processed and recovered for use in a variety of applications. These recovery technologies can convert waste into useful resources, thereby complying with circular economy concepts and minimizing the seafood industry's environmental impact. Proteins and lipids in wastewater can be recovered through enzymatic hydrolysis or physical-chemical treatment. These chemicals can be utilized to make fish meal, animal feed, and bioactive peptides. Fats and oils collected from wastewater can be utilized to make biodiesel or as raw ingredients for cosmetics and lubricants. The high organic load in seafood effluent makes it suitable for anaerobic digestion, which produces biogas (a mixture of methane and carbon dioxide). Biogas can serve as a renewable energy source. Waste oils and fats can also be transformed into biodiesel via transesterification. Effluents containing shellfish leftovers contain chitin, which can be processed into chitosan. Chitosan is a useful biopolymer with applications in water treatment, agriculture, and the pharmaceutical sector (Iqbal, 2014). There are some challenges to these resource recovery technologies also. The cost-effectiveness of recovery technologies must be evaluated based on the scale of the industry and the value of the recovered resources. The recovery process itself should have a minimal environmental impact to ensure sustainability.

Potential limitations include:

- Seasonal variability in effluent characteristics.
- Laboratory conditions not fully replicating field-scale complexities.
- Limited availability of real-time monitoring data for certain parameters.

RESULTS AND DISCUSSIONS

Survey Report: A survey was conducted on 4 seafood processing industries around the Rupsha Upazila of Khulna City in September of 2024. 2000-6000kg/day/plant shrimp was processed during that time. The seafood processing industry in Khulna has experienced a notable decline in recent years. In the fiscal year 2022-2023, Khulna exported approximately 19,900 metric tons of shrimp, a significant drop from the 39,706 metric tons exported in 2016-2017 (White, n.d.). Seafood processing factories produced an average of 800 to 2000 kg of solid waste per plant per day during the middle of September, which was approximately 35% of the total shrimp. Those plants were using around 5000-15000 L of water per day. Around 100% of the total water was converted into wastewater. Figure 3 illustrates the amount of waste, processed Shrimp, and water required for the processing of each 100 kg shrimp. The amount of wastage is approximately 35% of the raw shrimp.

ISBN: 978-984-35-7297-4

From those surveyed industries, it was shown that the types of solid waste produced by seafood processing factories are mentioned as follows:
Wastes from Packaging: Polythene, Papers, Plastics, Cartons, Polystyrenes, Jute ropes, Plastic ropes, Scotch tape, Labels, PP bands, Paper board, etc.
Wastes from Fish: Head, Shell, Flesh, Raw fish, Damaged fish, Tail, Fat, Shrimp fingers, etc.

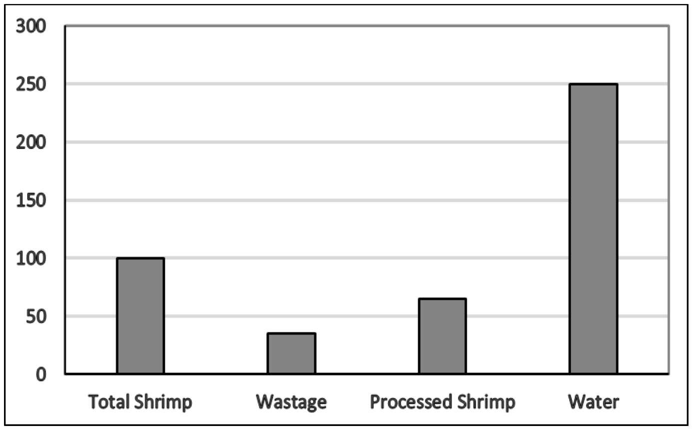

Figure 3 Wastage, Processed Shrimp, and Water per 100 kg of raw shrimp

Characterization of Seafood Industry Effluents: Table 2 shows the Physiochemical and Microbial Characteristics of Surveyed Seafood Industries' Effluent. Here, Turbidity (NTU) indicates the presence of suspended particles in wastewater. High turbidity levels, as seen in all industries, indicate poor water quality and potential consequences for aquatic ecosystems. pH measures the acidity or alkalinity of wastewater. The pH readings (7.90-8.40) are within the normal range for most environmental discharge guidelines (6.5-8.5), which is good. EC (Electrical Conductivity, mS/cm) indicates the concentration of dissolved salts in water. Values greater than 10 indicate high salinity, which may harm freshwater organisms and reduce soil quality if used for irrigation. Salt (%) indicates the salinity. Levels (0.87-1.20%) indicate substantial salt content, most likely owing to seafood processing. DO (Dissolved Oxygen, mg/L) represents the oxygen availability in wastewater.' Low levels (1.52-2.48 mg/L) suggest oxygen depletion, which can be detrimental to aquatic life. BOD (Biochemical Oxygen Demand, mg/L) measures pollution levels of organic matter. High values (309-415 mg/L) indicate a large organic load, implying poor treatment or high organic content in effluent. COD (Chemical Oxygen Demand, mg/L) reflects the overall amount of organic contaminants. The high COD (490-630 mg/L) confirms the elevated BOD levels and shows the need for strong treatment. TDS (Total Dissolved Solids, mg/L) shows the concentration of dissolved compounds. The values (1690-2123 mg/L) are high, which may impair water quality for reuse or discharge. TSS (Total Suspended Solids, mg/L) represents solids that can settle out of water. High concentrations (430-710 mg/L) may contribute to sedimentation and harm aquatic ecosystems. NO_3 (Nitrates, mg/L) indicates nutrient levels. Values (10.7–13.2 mg/L) are within acceptable limits for most discharge standards but could contribute to eutrophication in large amounts. Total Coliforms (c.f.u./100 mL) is a measurement of microbial contamination. High readings (2.1×10^3 to 3.3×10^3) indicate possible fecal contamination and health hazards. Fecal Coliforms (c.f.u./100 mL) are a part of Total Coliforms. High numbers (190-330 CFU/100 mL) suggest the necessity for disinfection before discharge or reuse.

Table 2 Physiochemical and Microbial Characteristics of Surveyed Seafood Industries' Effluent

Parameter	Industry-1	Industry-2	Industry-3	Industry-4	Disposal Point Average
Turbidity (NTU)	416	490	540	380	152
pH	8.10	8.16	7.90	8.40	7.50
EC ($mScm^{-1}$)	17.23	15.32	15.65	12.90	11.5
Salt%	1.20	0.97	0.99	0.87	0.4
DO (mgL^{-1})	1.82	1.79	2.48	1.52	3.18
BOD (mgL^{-1})	390	345	309	415	230
COD (mgL^{-1})	574	512	490	630	389
TDS (mgL^{-1})	2123	1860	1690	1943	1197
TSS (mgL^{-1})	710	633	430	560	198
NO_3 -	11.2	13.2	12.2	10.7	9.7
Total Coliforms (c.f.u/100mL)	$2.7×10^3$	$3.1×10^3$	$2.1×10^3$	$3.3×10^3$	320
Faecal Coliforms (c.f.u/100mL)	240	320	190	330	85

Insights: The study identified considerable contamination of neighboring soil and surface water bodies caused by untreated or inadequately treated effluent from seafood processing companies. High amounts of organic matter, nutrients (nitrogen and phosphorus), salts, and microbial diseases have been identified, posing threats to agricultural production, aquatic ecosystems, and public health. Salinity and nutrient enrichment in water bodies were particularly problematic since they might lead to eutrophication and deterioration of aquatic habitats. Similarly, soil contamination at discharge points indicates a negative influence on fertility and probable long-term consequences for regional land usage. High BOD and COD levels indicate pollution and require biological or chemical treatment. High salinity and TDS/TSS could make this water unsuitable for reuse or discharge without advanced treatment. Effective disinfection is necessary due to the presence of pathogens, such as coliforms.

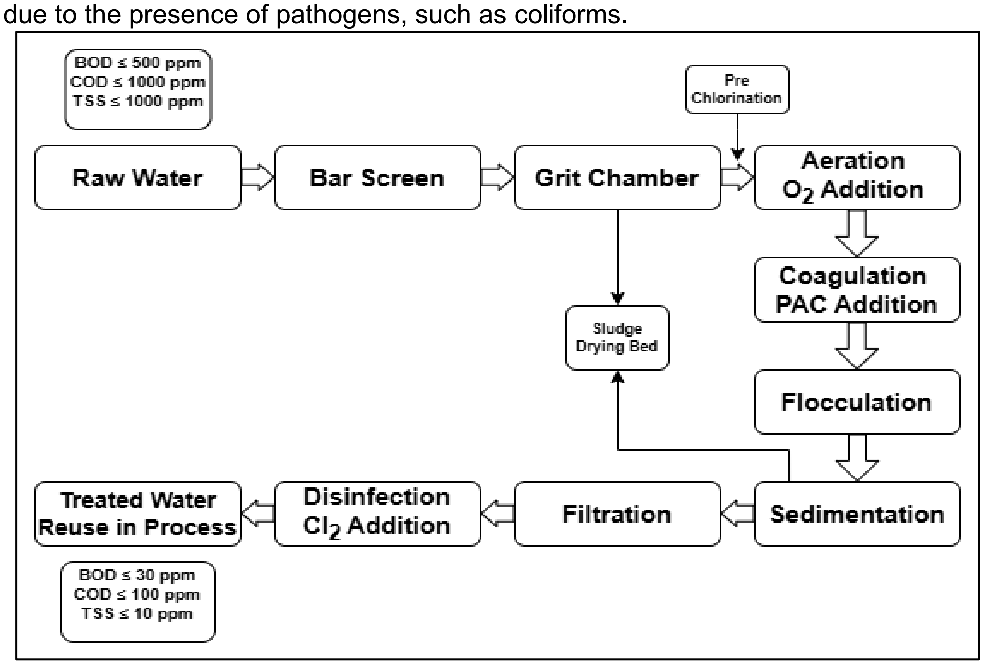

Figure 4 Effluent Treatment Plant Flow Diagram

According to the Environment Conservation Rule 2023(ECR-2023), the seafood processing industries are classified as “Orange Marked Industry”. Table 2 violates all of the parameters of effluent which is discharged to the environment specified by ECR-2023 except pH. That’s why, the effluent should pass through Effluent Treatment Plant (ETP) before discharging to the environment. One of those four industries had an ETP, but that wasn’t working. According to (Cornwell) a wastewater treatment plant is given below with different functional units. Figure 4 illustrates the different functional units of required ETP for those seafood industries’ effluent. The Effluent Treatment Plant (ETP) was designed using a conventional engineering process widely used in wastewater treatment systems. The effluent's quantitative and qualitative properties were considered. Here, in Table 3, is an overview of the different unit dimensions of the ETP needed for those industries. The ETP was designed using essential wastewater engineering principles and calculations to ensure that discharge guidelines. Table 3 shows the dimensions of different units for the treatment of a maximum of 20000 L/day effluent with a 1.2 peak factor.

Table 3 Overview of Different Unit's Dimensions (Capacity 20000L/day)

Component	Volume (m^3)	Dimensions (m × m × m)
Screening	-	Standard bar screen
Grit Chamber	10	Circular: D = 1.5 m, H = 1.5 m
Aeration Tank	4.233	2 × 1.5 × 1.5
Coagulation-Flocculation	0.417	1.5 × 0.75 × 0.5
Sedimentation Tank	3.75	2.5 × 1.5 × 1
Sand Filter	3.0	Circular: D = 1 m
Disinfection Tank	0.417	Circular: D = 1.2 m, H = 0.5 m

Effluents from the seafood industry are high in both inorganic and organic components that can be recovered and reused. These recovery efforts not only reduce environmental pollution but also give economic benefits by converting waste into valuable resources. Resource recovery has several benefits, including revenue generation from by-products, reduced environmental contamination, and conservation of resources. Maintaining discharge limitations and environmental standards; promoting zero-waste principles. By employing innovative technologies and taking an integrated approach, the seafood industry can transform effluent management into a resourceful and sustainable practice. Some of the major resource recovery opportunities: are biogas production, protein and amino acid recovery, oil and lipid extraction, nutrient recovery (nitrogen and phosphorus), collagen and gelatin recovery, water recovery, salt recovery, enzyme recovery, bioactive compound recovery, shell and bone-derived materials, and so on.

If the effluent is passed through the proposed ETP, the treated water will be ready for reuse in different applications of the industry. The treated water product of the proposed ETP has various applications. Cleaning, equipment cooling, and processing activities within the seafood industry are possible. Treated effluent water can be reused in fish farming if the salinity and quality match the requirements. If permissible, water can be used in agriculture with adequate pathogen and nutrient control. The oven-dry powdered sludge can be used as fertilizer as this is full of organic matter enriched in Nitrogen and Phosphorus.

Resource recovery from seafood processing industry waste is difficult due to several kinds of technological, economic, and logistical limitations. Organic objects in seafood wastewater decompose quickly, producing bad odors and reducing the quality of recoverable items. These seafood sectors are small or medium-sized, with insufficient economies of scale that justify modern treatment and resource recovery technology. Advanced treatment systems (such as anaerobic digesters, reverse osmosis, and enzymatic extraction) need large capital commitments. These industries may find it expense unfeasible to implement these systems. Except for water, this study is incompatible with other resource recovery methods. More research is needed on resource recovery from the seafood companies.

CONCLUSION

The seafood processing companies in the Khulna region are vital to the local economy, but they also contribute to environmental issues through effluent discharge. The findings highlight the importance of reducing the environmental concerns associated with effluent discharge, as well as prospects for long-term resource recovery. The study identified considerable contamination of neighboring soil and surface water bodies caused by untreated effluent from those seafood processing industries. The effluent's quantitative and qualitative properties were considered for designing an ETP with a capacity of 20000L/day with a peak factor of 1.2. An overview of the various unit dimensions of the ETP required for such companies is provided. Effluents from the seafood industry are high in both inorganic and organic components that can be recovered and reused. Resource recovery from seafood processing industry waste is difficult due to several kinds of technological, economic, and logistical limitations. However, the treated water product of the proposed ETP has various applications. Cleaning, equipment cooling, and processing activities within the seafood industry are possible. Treated effluent water can be reused in fish farming if the salinity and quality match the requirements. These seafood sectors are often small or medium-sized, with insufficient economies of scale that justify modern treatment and resource recovery technology. The author suggests further study on different resource recovery systems from those industries of the Khulna region.

REFERENCES

Basanta K. Barmon, M. C. (2011). Value Chain and Marketing Channels of Shrimp/Prawn Sector of Gher Farming System in Bangladesh. *World Review of Business Research, 1*(1), 10-24.

Billah, S. M. (2016). *Impacts of Effluents and Wastes of Shrimp Processing Industries on Soil and Water Environment in and around Khulna city.* Doctoral dissertation, University of Dhaka.

Cornwell, M. D. (n.d.). *Introduction to Environmental Engineering 6th Edition.* McGraw Hill.

Debanjon Shome, K. M. (2024). INTEGRATED PERFORMANCE ASSESSMENT OF BANGABANDHU WATER TREATMENT PLANT IN KHULNA. *7th International Conference on Civil Engineering for Sustainable Development (ICCESD 2024), KUET, Khulna, Bangladesh.* Khulna. Retrieved from http://www.iccesd.com/proc_2024/Papers/823.pdf

G. Vallini, A. P. (1989). Compost detoxification of vegetable-tannery sludge. *Waste Management & Research, 7*(3), 277-290. https://doi.org/https://doi.org/10.1016/0734-242X(89)90041-4

Iqbal, M. S. (2014). Production and characterization of chitosan from shrimp waste . *Journal of the Bangladesh Agricultural University, 12*(1), 153-160. https://doi.org/10.22004/ag.econ.209911

Md Jakiul Islam, E. E. (2021). *FISH WASTE MANAGEMENT AN ASSESSMENT OF THE POTENTIAL PRODUCTION AND UTILIZATION OF FISH SILAGE IN BANGLADESH, PHILIPPINES AND THAILAND .* Rome: FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS.

Sk. Shafiqur Rahman, N. N. (2010). STATUS OF STAKESHOLDERS OF SHRIMP MARKETING CHANNEL IN BAGERHAT DISTRICT WITH A VIEW TO ENVIRONMENTAL PROTECTION AND MANAGEMENT. *Khulna University Studies, 10*(1), 99-105. https://doi.org/https://doi.org/10.53808/KUS.2010.10.1and2.0818-L

White, C. (n.d.). *Bangladesh reports drastic decline in shrimp production*. Retrieved from Seafood Sources: https://www.seafoodsource.com/news/supply-trade/bangladesh-reports-drastic-decline-in-shrimp-production?utm