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RESEARCH

Application of collected shells as a bioremediator for fish pond effluent

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Abstract

The increasing pollution caused by effluent from fish ponds is a significant environmental concern, particularly in aquaculture. This study evaluates the use of snail and crab shells as bioremediators to treat fish pond effluent. Snail and Crab shells were purchased from local seafood markets and a snail farm, washed, dried, and homogenized by grinding to a small particle size. 100 g each of the shells was measured and introduced into 10 L of plastic rubbers designated as control (no treatment), Treatment 1 (snail shells), Treatment 2 (crab shells), and Treatment 3 (a combination of both). Fish pond effluent was collected from a nearby fish pond and filled into the plastic at 8.5 L. Physical and chemical parameters (Total Hardness (TH), Total Alkalinity (TA), pH, calcium, chloride, Dissolved Oxygen (DO), BOD, COD, temperature, and Electrical Conductivity (EC) of the effluent water were measured three times weekly for 21 days. The Results indicate that Treatments 2 and 3 significantly improved water quality compared to the control and Treatment 1. T2 and T3 had greater reductions in BOD (1.26 and 1.24 mg/L, respectively) and COD, along with increases in TH, TA, and calcium content, demonstrating the effectiveness of crab shells in particular. T1 exhibited moderate improvements but was less effective than T2 and T3. Additionally, physical observations showed that T2 and T3 produced biofilms and microbial activity, which disappeared by Day 10. The study concludes that shell-based bioremediation is a sustainable, eco-friendly method for improving aquaculture effluent quality. Further research is recommended to optimize this technique for larger aquaculture systems and explore its economic feasibility.

Keywords Bioremediation · Fish pond effluent · Snail shells · Crab shells, and water quality

Introduction

The aquaculture sector is essential to the world's seafood supply, but intensive fish farming methods frequently produce effluent contaminated with different types of pollutants, creating environmental problems. The effluent from fish ponds usually contains

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Extended author information available on the last page of the article nutrients, organic matter, and potentially hazardous materials that, if improperly handled, can deteriorate water quality and damage aquatic ecosystems. Using acquired shells as an organic remediation agent for fish pond effluent is one promising way to address these environmental concerns. Shells, which can be obtained from seafood processing sectors or collected as waste, have specific characteristics that make them useful for treating effluent and reducing its harmful effects on the environment (Vazhiyil and Sasidharan 2021).

A variety of contaminants can be found in the wastewater from fish ponds, such as excess nutrients like phosphorus and nitrogen, organic debris from fish excrement, uneaten feed, heavy metals, and pathogens, which can be dangerous. This effluent poses a threat to aquatic life and ecosystems because it can cause eutrophication, oxygen deprivation, and the growth of hazardous algal blooms when released into nearby water bodies (Topić Popović et al. 2023). Traditional approaches for treating wastewater, like chemical disinfection and mechanical filtration, frequently need a large energy input and may produce secondary contaminants. On the other hand, utilizing gathered shells as a remediation solution presents a viable and eco-friendly substitute. Shells, which are mostly made of calcium carbonate, have a number of characteristics that make them ideal for treating wastewater. First, there are many places for contaminants to adsorb and precipitate due to their large surface area and porous nature. In addition, calcium carbonate functions as a buffer, assisting in the stabilization of pH levels in acidic effluent and averting rapid changes that could endanger aquatic life. (Topić Popović et al. 2023).

Snails belong to the phylum Mollusca and the class Gastropoda. The gastropods are the largest class of the phylum Mollusk (Gadzama et al. 2017), a group of animals commonly known as snails and slugs. While crabs belong to the phylum Arthropoda, subphylum Crustacea. Snail and crab shell naturally have hard shell which protects them from physical damage, predators, and dehydration. Recent development involves its application in the treatment of water and wastewater as a result of its chemical composition and large surface area; this composition includes proteins, carbohydrates, fats, and minerals such as iron, zinc, copper (Jatto et al. 2020). According to (White et al. 2007) shells consist of 95–99.9% calcium carbonate and 0.1–5% organic material by weight which includes proteins, polysaccharides, and lipids. (Suzuki and Nagasawa 2013), indicated that shell have trace amounts of magnesium (Mg) and strontium (Sr), and as such, the biological processes and environmental conditions determine the Sr/Ca or Mg/Ca ratios. The main component of shells, such as those of snails and crabs is calcium carbonate, found in the mineral form of calcite and aragonite. The ratio of calcite to aragonite can vary among different mollusc species, influencing the shell's mechanical properties and resilience to environmental factors (Taylor et al. 2016). Additionally, these shells include trace amounts of organic molecules and proteins, which may impact their chemical and physical characteristics. Their high calcium content greatly aids the use of shells for water purification.

Researchers have focused a lot of attention on marine shell resources because of their special qualities, which include high adsorption, bioactivity, corrosion resistance, good toughness, and high hardness (Cheng et al. 2023). Therefore, their porous shape facilitates effective filtering by capturing particulate matter and suspended solids when water flows through them.

Nitrogen and phosphorus are the two primary nutrients present in fish pond wastewater that require consideration. Fish excrement, garbage, and other organic materials decompose in the pond to provide these nutrients. Therefore, high concentrations of these nutrients have the potential to cause eutrophication, which is defined as an excessive growth of aquatic plants and algae in receiving water bodies.

Beyond nutrient pollution, fish pond effluent can also harbor Pathogenic microorganisms, such as bacteria, viruses, and parasites, can be found in fish pond effluent posing additional risk to ecosystem as well as presenting health concerns to both humans and wildlife (Shariff et al. 1994).

However, aquaculture practices which could involve using antibiotics, and other chemicals, may result in the presence of these substances in the effluent. Information about the use of crab and snail shells as an adsorbent is limited in literature. Most related information available in literature is on the use of chitosan in the treatment of wastewater (Pankaj et al. 2023). Gong et al. (2019) reported that the surface charge of calcium carbonate in shells plays a significant role in adsorbing and removing charged pollutants from water. Furthermore, using natural materials like shells is an affordable and environmentally friendly alternative that works well for large-scale aquaculture operations.

The use of chemical to treat effluent water can disrupt pH and harm ecosystem, therefore, this study aims at using snail and crab shells to adsorb nitrate, phosphates and other harmful chemicals presence in fish pond effluent and to stabilize water condition, enhance organic waste breakdown and provide ecofriendly, cost effective and sustainable waste recycling.

Materials and methods

Materials

The materials used for this study include crab and snail shells, gloves, bags, Basins, mortar and pestle, sieves, large bowls, labels and markers, measuring containers, stirring rods, kegs, pH meter, (pHS-25: Model) DO meter, EC meter (Model: Jenway-4010) sample bottles, pipettes and graduated cylinders, weighing balance (Golden Mettler 2000L: Model), thermometer.

Preparation of the shell

Snail and crab shells were collected from local seafood markets, snail farms and washed to remove organic matter, pollutants and sun-dried. To improve the remediation efficiency, thereafter the dried shells were crushed into smaller pieces using a mortar and pestle to enhance their surface area. Thereafter, they were sieved to achieve uniform particle sizes (0.5- 1 mm). According to (Smith and Jones 1985).

Fish pond effluent collection

Earthen fish pond effluent samples were collected during draining through outlet from fish farms ensuring it represents typical conditions which includes normal characteristics of pond effluents. The pre-analysis of the pond effluent was done to determine the level of the following physical and chemical parameters: pH, turbidity, nitrogen, phosphorus, and heavy metals (Table 1, 2, and 3).

Table 1 Pre and Treatment Analysis of Physical and Chemical Parameters of Fish Pond Effluent. These values reflect the condition of the effluent prior to and during the treatment and provide a baseline for comparison with the treatment effects were measured

			Treatments					
Parameters mg/l	Pre-Analysis	CTRL	T1	T2	T3	SEM	P-value	LS
TH	46	67.29^{a}	100.10^{a}	295.29^{b}	242.86^{b}	27.18	0.002	*
TA	28.67	65.86^{a}	74.14^{a}	252.43^{b}	210.91^{b}	24.9	0.005	*
pH	6.65	7.06^{a}	6.96^{a}	7.16^{a}	7.39^{a}	0.09	0.405	NS
Calcium	42	45.25^{a}	79.19^{ab}	150.20^{b}	108.39^{ab}	14.9	0.072	NS
Chloride	10.59	19.07^{a}	21.44^{ab}	31.66^{b}	25.47^{ab}	1.84	0.072	NS
DO	1.6	4.33^{b}	3.93^{b}	1.79^{a}	1.73^{a}	0.33	0.001	*
BOD	1.4	3.09^{b}	2.56^{b}	1.26^{a}	1.24^{a}	0.23	0.002	*
Temperature	27.77	26.78^{a}	27.41^{a}	26.91^{a}	26.51^{a}	0.18	0.355	NS
COD	24	20.30^{a}	19.45^{a}	17.55^{a}	18.55^{a}	0.78	0.652	NS
EC μS/cm	282	301.29^{a}	530.95^{a}	2458.38^{c}	1699.95^{b}	214.23	0	*

Mean values in the same row followed by the same superscript are not significantly different ($p > 0.05$)

SEM = standard error mean, TH = total hardness, TA = total alkalinity, pH = Acidity, DO = dissolved oxygen, BOD = biochemical oxygen demand, COD = chemical oxygen demand, EC = electrical conductivity, CTRL = Control, T1 = Treatment 1, T2 = Treatment = 2, T3 = Treatment 3, SEM = Standard Error of the Mean, LS = Least Squares

Table 2 Physical Observations of the Fish Pond Effluent Treated with Shell for one Week Period

Days	Physical Observations
Day 1	All treatments, including T1 (snail shell treatment), T2 (crab shell treatment), T3 (combination of snail and crab shells), and the control, appeared highly turbid with a strong, unpleasant odor No significant difference in turbidity was noted initially, but T1 appeared to be the least turbid, while T2 showed the most turbidity
Day 3	T2 began to exhibit visible suspended solids in spherical shapes, indicating the presence of organic material aggregation or shell fragments reacting with effluent components. The control group still exhibited uniformly dispersed Turbidity
Day 5	Particles in the control group began to settle, resulting in a clearer supernatant at the top. Meanwhile, T2 continued to display the highest levels of turbidity with suspended solids, while T1 remained the least turbid. Both T2 and T3 began to develop a strong, unpleasant odor. The odor was stronger in T2 compared to T1 and the control
Day 7	By the end of the first week, T2 and T3 developed a gelatinous, slimy layer on the surface, indicating a biofilm or microbial mat formation. This phenomenon was likely due to bacterial and algal growth promoted by the nutrient-rich environment, as well as biological activity resulting from organic breakdown

Table 3 Physical Observations of the Fish Pond Effluent Treated with Shell for Two Weeks Period

Days	Physical Observations
Day 9	The gelatinous layer on T2 and T3 disappeared. Larvae and worm-like organisms became more active after this disappearance, potentially feeding on the microbial content. The effluent in T2 still displayed significant turbidity and suspended solids, but the smell became minimal
Day 11	The effluent in T2 still displayed significant turbidity and suspended solids, but the smell became minimal. T1 remained relatively clear with no noticeable biofilm formation
Day 14	At the end of the experiment, T1 had the clearest effluent, with minimal turbidity or odor. T2 and T3 also became clearer with a slight blue-green hue The control effluent maintained a degree of turbidity but exhibited particle settling and less odor compared to T2 and T3

Remediation process

The African Blue Crab (*Callinectes spp.*) and the Giant African Snail (*Achatina achatina*) shells were used in this study. A total of 4500 g, comprising of 2250 g of Snail shells and 2250 g of crab shells were collected in a container and placed on weighing balance (Golden Mettler 2000L: Model) and crushed using mortar and pestle. 500 g of these shells were added to each treatment basin containing 10 L of pond effluent at 22.73 g/l (required grams of effluent in the pond effluent in litres). Specifically, 500 g of snail shells were introduced in three basins, and 500 g of crab shells in another three basins. Finally, a combination of both shells at 250 g each, were introduced into treatment three. To ensure even distribution of the shells, the shells were gently stirred. For the control basin to function as a baseline for comparison, crushed shells were not included.

Water quality monitoring and data collection

The treatments were monitor and observed regularly for a period of two weeks; analysis was carried out bi-daily. The parameters measured include: pH, turbidity, total alkalinity, total hardness, chloride, calcium, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, electrical conductivity, and temperature. The water temperature was determined using a mercury thermometer by submerging it in the water for five minutes until a stable reading was obtained, which was then recorded. pH and dissolve oxygen were determined with pH meter and DO meter respectively. The water temperature was determined using a mercury thermometer by submerging it in the water for five minutes until a stable reading was obtained, which was then recorded.

Determination of BOD

Biological oxygen demand (BOD) was determined using the azides modification method by measuring initial dissolved oxygen (DO), incubating the sample in the dark for five days, then remeasuring DO; BOD (mg/L) was calculated as the difference between initial and final DO.

Experimental design

A Complete randomized design comprising of four treatments and three replicates was used in this study. The treatments were designated as Ctrl (Control), T1 (Snail shell), T2 (Crab shell), and T3 (Combination of Snail and Crab shell), each replicated three times ($4X3 = 12$).

Statistical analysis

Data obtained was subjected to ANOVA using SPSS version 23 and the mean was separated using DUNCAN multiple range test. Homogeneity of variance was performed during ANOVA analysis The significant level was taken at ($p < 0.05$).

Results

This chapter presents the results of a 14-days water quality analysis, during which data were collected every other day, resulting in a total of 7 data collection points. The treatments included a control (CTRL), Treatment 1 (T1), Treatment 2 (T2), and Treatment 3 (T3). The parameters assessed include Total Hardness (TH), Total Alkalinity (TA), pH, Calcium (Ca), Chloride (Cl^-), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Temperature (Temp), Chemical Oxygen Demand (COD), and Electrical Conductivity (EC).

Pre and treatment analysis of water quality parameters

Before applying treatments, the baseline water quality parameters were recorded. The initial and treatment values are summarized as follows:

Results

The results in Table 1 indicate that the use of crab shells (T2 and T3) had the most significant impact on water quality improvement, particularly in increasing hardness, alkalinity, calcium, and chloride levels. The BOD and COD reductions in T1, T2, and T3 suggest the treatments were more effective in reducing organic pollutants and increasing oxygen demand. T1, which involved snail shells, was less effective but still improved water quality compared to the control.

The treatments significantly influenced the water's total hardness, as shown in Table 1. The initial hardness of 46 mg/L increased across all treatments, with the most significant changes observed in T2 (295.29 mg/L) and T3 (242.86 mg/L). T1 had a much lower increase in hardness (100.10 mg/L), while the control group maintained the lowest hardness values (67.29 mg/L). There were significant differences ($p < 0.05$) between the treatments, with T2 and T3 having significantly higher hardness levels compared to the control and T1. The increased hardness in T2 and T3 may be attributed to the release of ions from the crab shells, which are known to contain high levels of calcium and magnesium (Wong 2019). This suggests that crab shells can effectively increase the hardness of water, which could be beneficial in specific aquaculture systems. According to Goh and Lim (2005), calcium-rich materials such as shells can increase the total hardness of water, contributing to better buffering capacity and stability of pH levels.

The total alkalinity followed a similar trend to total hardness, with significant increases in T2 (252.43 mg/L) and T3 (210.91 mg/L). T1 exhibited only a slight increase in alkalinity (74.14 mg/L), while the control remained at 65.86 mg/L. There was a significant difference ($p < 0.05$) between the treatments. T2 and T3 had higher alkalinity compared to the control and T1, highlighting the effectiveness of crab shells in releasing buffering ions into the water. This increase in alkalinity is important for maintaining pH stability, as noted in previous studies (Morris et al. 2020). The pH levels across all treatments remained relatively stable, with no significant changes ($p > 0.05$). The pH values ranged from 6.96 in T1 to 7.39 in T3, all within acceptable limits for aquatic life (Boyd and Tucker 2012). While there were minor fluctuations, none of the treatments resulted in drastic pH changes, suggesting that the shells did not significantly alter the acidity or basicity of the water.

The calcium content of the water increased in all treatments, with T2 showing the highest levels of calcium (150.20 mg/L). T3 followed with 108.39 mg/L, while T1 had a moderate increase (79.19 mg/L). The control group remained at 45.25 mg/L. This indicates that crab shells (T2 and T3) released more calcium into the water compared to snail shells (T1). There was no significant difference ($p > 0.05$), suggesting the differences were not strong enough to establish clear treatment superiority. Chloride concentrations increased significantly in T2 (31.66 mg/L) and T3 (25.47 mg/L) compared to the control (19.07 mg/L). This can be attributed to the ionic exchange that occurred during the treatment process, particularly in treatments involving crab shells.

Shell-based treatments, particularly those involving crab shells, have been shown to facilitate ionic exchanges that increase chloride concentrations in treated water (Chen et al. 2019).

Dissolved oxygen levels showed significant variation across the treatments, with T1 maintaining higher DO levels (3.93 mg/L) compared to T2 and T3 (1.79 and 1.73 mg/L, respectively). The control group had the highest DO levels (4.33 mg/L), likely due to minimal organic matter decomposition. The differences in DO between treatments were statistically significant ($p = 0.001$). Lower DO levels in T2 and T3 may be attributed to the higher biological activity and organic matter present in these treatments, which consumed more oxygen (Patel et al. 2022).

The BOD levels decreased in all treatments, with the most significant reductions observed in T2 (1.26 mg/L) and T3 (1.24 mg/L). T1 had a slightly higher BOD (2.56 mg/L), while the control remained at 3.09 mg/L. The reduction in BOD across treatments highlights the efficiency of the shell-based treatments in reducing organic pollutants. BOD is a key indicator of organic pollution, and lower BOD levels suggest improved water quality due to the breakdown of organic materials facilitated by shell treatments (Varank et al. 2012). COD values showed moderate reductions across the treatments. T3 exhibited the lowest COD (18.55 mg/L), followed by T2 (17.55 mg/L), T1 (19.45 mg/L), and the control (20.30 mg/L). Although these reductions were not statistically significant ($p = 0.652$), they suggest that shell-based treatments can help reduce both organic and inorganic contaminants.

Electrical conductivity (EC) increased significantly in T2 (2458.38 µS/cm) and T3 (1699.95 µS/cm), reflecting the higher ion concentrations released by the crab shells. T1 had a moderate increase (530.95 µS/cm), while the control group showed minimal change (301.29 µS/cm).

The ANOVA results indicated significant differences ($p < 0.001$), with T2 and T3 having much higher EC values than the control and T1. This is consistent with the increased ionic content resulting from the treatment process (Namasivayam and Sureshkumar 2009). The findings of this study align with previous research demonstrating the potential of shell-based bioremediators for improving water quality (Hu et al. 2011). Shell materials provide a sustainable and cost-effective solution for treating aquaculture effluents, particularly in systems where hardness and alkalinity need to be maintained or increased Fig. 1.

Physical observations

These observations suggest that the snail shells were more effective in reducing turbidity and minimizing unpleasant odors, while the crab shells appeared to cause more biological activity and suspended solids. The combination of both shells showed mixed results, with better turbidity reduction than Treatment 2 but more bioactivity and odor formation than Treatment 1.

Discussion

The efficacy of shell-based bio-remediators (snail and crab shells), in improving the water quality of fish pond effluents shows varying degree of purification, physical characteristics, and bioactivities. The analysis of Total Hardness, Total Alkalinity, pH, Calcium,

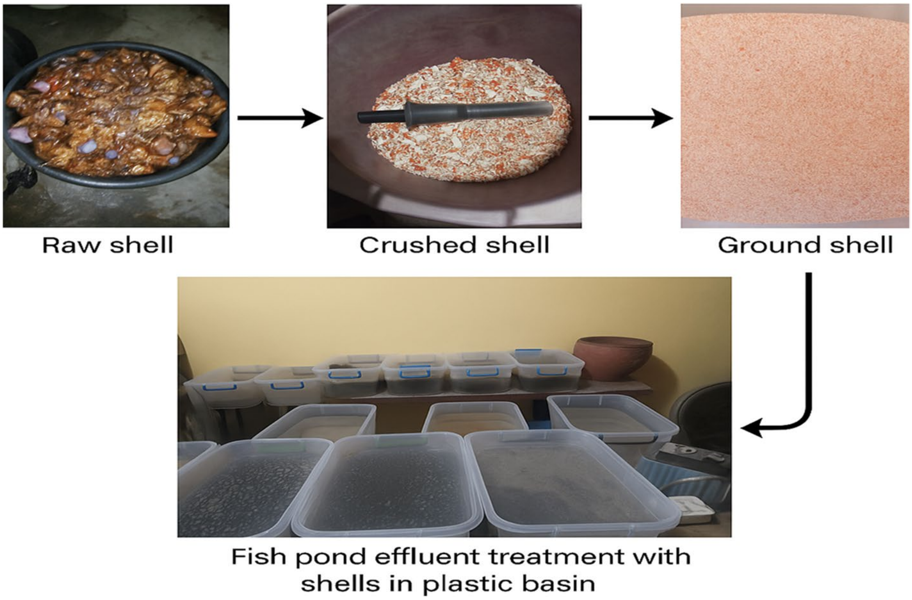

Fig. 1 Flow chart of Raw shell, crushed shell, ground shell and treatment of the earthen fish pond effluent with the shells. Source: (Author, 2024)

Chloride, Biochemical Oxygen Demand, Dissolved Oxygen, Temperature, Chemical Oxygen Demand, and Electrical Conductivity shows variation across all the treatments. Takarina et al. (2024) reported that the efficiency of shell to adsorb and purify contaminated water depends on water parameters.

The baseline water quality parameters of the effluent were measured, revealing initial values of 46 mg/L for Total Hardness, 28.67 mg/L for Total Alkalinity, and 1.6 mg/L for Dissolved Oxygen. The data showed notable differences between the treatments, with T2 and T3 performing better in improving water quality compared to T1 and the control. Specifically, the use of crab shells (T2 and T3) resulted in greater reductions in Biochemical Oxygen Demand and Chemical Oxygen Demand, while also significantly improving Total Hardness, Total Alkalinity, and Dissolved Oxygen levels. In contrast, T1 exhibited relatively lower performance but still improved water quality significantly compared to the control.

Finally, the findings demonstrated that the combination of snail and crab shells was the most effective treatment in enhancing water quality, followed by the crab shell treatment. The results suggest that shell-based bioremediators can play a vital role in sustainable aquaculture by mitigating effluent contamination, improving oxygen levels, and reducing organic pollutants in water. Nhung, et al. (2023) demonstrated the effective use of shells as coagulant materials in wastewater treatment. According to Parveen et al. (2020) research on physical and chemical analysis of three different freshwater snail species suggested that shells can make strong and mechanically sustainable biological materials applied in various fields including bioremediation.

The study revealed significant increases in Total Hardness (TH) and Total Alkalinity (TA) in the treatments involving crab shells (T2 and T3). Analyses confirmed that both T2 and T3 significantly improved TH and TA compared to the control and T1 ($p < 0.05$). This can be attributed to the high calcium and magnesium content in crab shells, which are released into the water during the treatment process (Goh and Lim 2005). pH, ambient temperature, play a crucial role in the degradation process. Shells degrade more rapidly under low pH conditions (Waldbusser et al. 2011) and high temperatures (Babarro et al. 2023). Lagos et al. (2016) report that the rate of shell degradation tends to increase at a pH of 7.7 and with increasing temperature.

Calcium, present in both snail and crab shells, is known to enhance water hardness and alkalinity by buffering and maintaining mineral balance in aquatic environments (Morris et al. 2020).

In aquaculture, increased hardness and alkalinity are beneficial as they help to stabilize pH levels and prevent wide fluctuations that could harm aquatic organisms (Boyd and Tucker 2012). The rise in hardness in T2 (295.29 mg/L) and T3 (242.86 mg/L) is particularly relevant for managing water chemistry in fish ponds, as harder water can better buffer against the acidification that occurs due to fish waste and feed breakdown. On the other hand, T1 (100.10 mg/L), which used snail shells, had a lesser impact on hardness and alkalinity compared to T2 and T3, likely due to the relatively lower calcium content in snail shells compared to crab shells (Wong 2019).The pH levels remained relatively stable across all treatments, with values ranging from 6.96 to 7.39. This range is optimal for aquatic life, as extreme pH levels can be detrimental to fish and other organisms (Patel et al. 2022). The ability of the treatments to maintain a neutral pH can be attributed to the buffering capacity of calcium carbonate in the shells, which neutralizes acidic components in the effluent (Chen et al. 2019). The increase in calcium content, particularly in T2 (150.20 mg/L) and T3 (108.39 mg/L), aligns with the release of calcium ions from the shells into the water. Calcium plays a critical role in regulating osmotic balance and supporting the skeletal development of fish (Morris et al. 2020). Higher calcium levels, as seen in T2 and T3, indicate that crab shells provide a rich source of calcium, enhancing the mineral content of the water. This not only contributes to the overall water quality but also supports fish health and growth.

The BOD and COD reductions observed in the treatments were notable, with T2 (1.26 mg/L for BOD; 17.55 mg/L for COD) and T3 (1.24 mg/L for BOD; 18.55 mg/L for COD) outperforming T1 and the control. BOD measures the amount of oxygen required by microorganisms to decompose organic matter, while COD represents the total quantity of oxygen needed to oxidize both organic and inorganic substances in water. Lower BOD and COD values reflect improved water quality, as there is less organic pollution (Varank et al. 2012). The reduction in BOD and COD in T2 and T3 is indicative of the shells' ability to adsorb organic pollutants and promote the breakdown of organic materials (Hu et al. 2011). The porous structure of the crab shells likely enhances microbial colonization, facilitating the decomposition of organic matter. This aligns with previous research on the use of shell waste in bioremediation, where shells have been shown to remove organic and heavy metal pollutants from wastewater (Wong 2019).

T1, which used snail shells, showed a moderate reduction in BOD and COD, but the results were less significant compared to T2 and T3. The lower performance of T1 may be due to the snail shells'comparatively lower capacity to support microbial activity or adsorb pollutants. However, T1 still demonstrated a marked improvement over the control, indicating that snail shells can contribute to bioremediation, albeit to a lesser extent than crab shells.

Dissolved Oxygen (DO) is one of the most critical parameters for assessing the health of aquatic environments. In this study, the control group maintained the highest DO levels (4.33 mg/L), followed by T1 (3.93 mg/L). In contrast, T2 and T3 had lower DO levels (1.79 and 1.73 mg/L, respectively). The reduction in DO in T2 and T3 can be attributed to the higher organic load in these treatments, which required more oxygen for decomposition, this align with the finding of Liu et al. (2016), Leal et al. (2018) and Coldebella et al. (2018), aquaculture effluents cause variations in water quality such as: decreased dissolved oxygen concentration, increased biological oxygen demand, nitrogen and phosphorus.

Although lower DO levels were observed in T2 and T3, these treatments also showed the most significant reductions in BOD and COD, suggesting that the organic pollutants were being effectively decomposed, albeit at the expense of available oxygen. In aquaculture, maintaining adequate DO levels is essential for fish survival, and the treatments that reduced organic matter could potentially alleviate future oxygen demand by reducing the concentration of decomposable organic matter in the long term (Boyd and Tucker 2012).

Electrical Conductivity (EC) is a measure of the water's ability to conduct electricity, which is directly related to the concentration of dissolved ions. The significant increase in EC in T2 (2458.38 µS/cm) and T3 (1699.95 µS/cm) reflects the higher ionic content released from the crab shells during treatment. Crab shells contain high levels of calcium, magnesium, and other minerals, which contribute to the increase in conductivity (Namasivayam and Sureshkumar 2009).

While higher EC values indicate increased ion concentrations, this can be beneficial for aquaculture if managed properly. Fish species have varying tolerances to water salinity, and increasing the ionic strength of water can help improve osmoregulatory functions in fish (Wong 2019). However, excessively high EC values can lead to increased salinity, which may not be suitable for all aquatic species. T1 had a much lower increase in EC (530.95 µS/cm), indicating that snail shells released fewer ions compared to crab shells.

Conclusion

The findings from this study demonstrate that the use of Crab shells (T2) alone is effective in treatment of fish pond effluent by significantly increasing the hardness and alkalinity of the water while reducing organic pollutants. Similarly, the combination of crab and snail shells proved to be more effective in reducing organic pollutants (BOD and COD), increasing Total Hardness (TH) and Total Alkalinity (TA), and releasing beneficial minerals like calcium into the water. Base on the finding, shell-based bioremediation is a viable, cheap and eco-friendly method for treating aquaculture effluents.

Recommendations

Future studies should investigate the scaling up of this bioremediation technique for use in larger aquaculture systems.

It would be beneficial to test the efficacy of these treatments in different aquaculture environments (fresh and brackish water systems).

The current study was conducted over 14 days, which provides insights into short-term water quality improvements. However, long-term studies should be conducted.

While this study focused on the use of shell-based materials, future research could explore the combination of these treatments with other natural bioremediation agents, such as bacteria or algae, to enhance the removal of specific pollutants.

Author contribution All authors contributed to the write up and review of the manuscript.

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflicts of interest The authors declare no competing interests.

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