Evaluation of different water filtration systems functions in shrimp farms

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Abstract

The shrimp industry has always relied on sustainable production to survive in this country. One of the solutions to achieve this goal, the prevention of pathogens and their carriers entering shrimp ponds, has been This study compared the efficacy of three-row with one-row water filtration systems in shrimp farms in Bushehr province. The three-row filtration systems consisted of different nets (1000, 500, and 250 microns), with three repetitions, while in the one-row system, only one row of 1000-micron mesh was used. These systems were utilized from the beginning to the end of the rearing period. This study analyzed data on unwanted shrimp, fish, and other species collected through the above systems. Based on the rearing period results, a three-row filtration system with 1000, 500, and 250-micron nets were the most effective in preventing entering particles (living and nonliving), unwanted organisms, eggs, and larvae of aquatic species. However, one-row filtration systems were the least efficient when compared to three-row systems in terms of efficiency. In addition, the number of unwanted organisms collected in shrimp processing centers confirms this issue. Also, in one-row filtration systems, increasing unwanted organisms caused a decrease in the production of 1300–2400 kg/ha, as well as profitability and increased production costs on farms. Compared the performance of the three-row filtration system was higher than that of one-row filtration. Any increase in unwanted organisms in shrimp ponds can lead to diseases because they are pathogen agent carriers. The results obtained indicated that farmers should use sand and micron filters with 1000 (row 1), 500 (row 2), and 250 (row 3) microns, respectively, to improve production, prevent pathogenic agents from entering, and reduce disease risk.

Keywords: Shrimp farming, Filtration, Micron mesh, Disease, Unwanted organisms

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Introduction

The global production of aquatic products and the supply of marine products have constantly been growing in recent years, so that fishery products have been able to play a very important role in the food security of the world's people by providing 15% of animal protein (FAO, 2021). Among the various production industries, the shrimp industry, as a foreign exchange industry, has been able to contribute to the preservation of natural reserves by reducing fishing from natural resources (seas) and creating jobs for residents of the country's southern coasts (Metinfar *et al*., 2009). The success of aquaculture depends on the availability of suitable water and soil. These factors play a crucial role in how well this industry performs (Abdullah Mashaei and Payghan, 1998; Chang *et al*., 2020). Despite an increasing trend in shrimp production during the years 2005-2019 in the country, it has not been able to reach the 60 thousand tons of production predicted in the sixth development plan until 2021 (Iran Fisheries Organization, 2019). Today, *Litopenaeus vannamei* is the most common shrimp species in Iran. Based on the Iranian Fisheries Organization's non-documented statistics, 56 thousand tons of this species were harvested by the end of 2021. During these years, outbreak disease has been one of the major reasons for the decline in shrimp production rates in the country. Disease outbreaks in shrimp farms can significantly affect the profitability and development of this industry. Infectious pathogens such as viruses, bacteria, fungi, and parasites continually threaten this industry (Coutteau, 2016). Over the past years, the outbreak of white spot virus disease has been one of the main causes of industry stagnation and production reduction in shrimp farms in the country (Afsharnasab *et al*., 2014; Gholamhosseini *et al*., 2020). Due to the existence of different shrimp farming systems, the shrimp farming system used in Iran is a semi-intensive system (Ismaili Sari, 2000). In addition to the more favorable economic justification of this system than the extensive system, it also has given a glimpse of shrimp farming in intensive systems (Yap and Landoy, 1993; Shang *et al*., 1998). In many shrimp farms, ponds are dewatered by pumping water with 10 or 12-inch electronic pumps; at the same time, when the pump is turned on, a large volume of water containing objects and unwanted organisms can enter the farming ponds. Therefore, this water can be a carrier of pathogens agents. Water is a suitable environment for aquatic organisms, so that it can contain many pathogens agents. As a result, a lot of diseases can be horizontally transmitted from these agents to cultured shrimps (Courtland, 1999; Saraswathy *et al*., 2016; Xu *et al*., 2021). In shrimp farms, the water should be free of pathogenic agents, so water preparation is one of the most basic steps in shrimp farming (Soto *et al*., 2001; Biao *et al*., 2009; Ng *et al*., 2018). In order to increase aquaculture production, it is always necessary to comply with biological safety measures on the farm. In view of this, it is necessary to prevent disease agents from entering shrimp ponds through water before dewatering them (Suantika *et al*., 2018). To increase shrimp farm production and prevent diseases, pathogenic agents must not enter the shrimp farming ponds directly or via carriers such as other shrimp species, wild fish, crabs (or other crustacean) and or other unwanted organisms. One of the ways to prevent the entry of pathogenic agents and their carriers into the farming ponds on the farm is the construction of physical barriers, such as the installation of multi-row filtrations accompanied by micron filters. But using a net of 1000 microns (1 mm) cannot be effective in preventing the entry of carriers of pathogens agents. This study evaluated the efficiency of the old and the newly designed water filtration systems in preventing the entry of pathogens carries and unwanted organisms into ponds in Bushehr province by creating a structural change in the water multiple filtration systems.

Material and method

To improve the efficiency of the water filtration system in shrimp farms, a number of structural reforms were carried out in different parts of the filtration system in Delvar shrimp farms in Bushehr province. As mentioned, in Bushehr province, shrimp farms are usually supplied with water by pumping it from main irrigation canals based on seawater tides. There is no physical filter at the entrance of the water supply channel from the sea; therefore, plenty of fish and other aquatics enter these channels through seawater also during the year due to the water in the channel, and as a result, this place has become the habitat of many aquatics. Many of these organisms can carry viral, bacterial, fungal, parasitic and other pathogens agents. Therefore, their entry into shrimp ponds is always associated with problems, such as increased food competitors and the transmission of pathogenic agents (Primavera, 1992; Prayitno *et al*., 2022). The dewatering system in shrimp ponds consists of different parts. These parts include a water suction basin, water suction pipe (valve), pumps, water relaxation basin, filtration pool and irrigation water channel in the field. Each of these parts should have its own structural characteristics in order to improve the efficiency of the dewatering system in shrimp farms (Figure 1).

Figure 1: Suction basin and filters, with the aim of preventing unwanted entry.

In this study, all parts of the water preparation system except the filtration pool were similar in both filtration systems. The suction ponds in both systems (one and three row filtration) were surrounded by a plastic net with a hole of 20 mm to the bottom of the irrigation water channel, and cotton nets also covered the upper part of the pond (5-10 mm) so that they prevented entry crabs and other aquatic to the pond. The water suction pipe (valve) is located in the deepest part of the water suction basin. A metal net with a hole of 10-20 mm was used to filter around the pump valve to prevent unwanted creatures from entering the pool. Based on the system designed in the shrimp farms, the ponds are drained by pumping water from the irrigation water channel by 10 or 12-inch electronic pumps. The power of each of these pumps is 37 to 75-kilowatt hours with 3000 rpm. Generally, water is drawn from the fields 12-15 hours a day, depending on the amount of water available in the irrigation water channel and the tidal state in day and night. Typically, farm water relaxation ponds are 3 x 6 meters with a 5-meter depth. This pond was built to reduce pumped water pressure. As a result, coarse stones (20-30 cm) and small rubble (more than 2-3 cm) were used on the bottom of this pond and, between them, placed a metal net with a 1-cm hole. Also, at the bottom level of this pond is a central backwash outlet (Figure 2).

Figure 2: The rubble placed on the metal and plastic net of the calm pond.

By modifying the irrigation system of farms and building a three-row filtration pond, this study attempted to compare the efficiency of this system with the old system in the fields (use of a 1000-micron net). This pond was made of a concrete structure measuring 25 x 5 meters. Micron nets were installed in three rows with a distance of 6 to 5 meters, with four to five outlets in each row. As for the one-row system, only one net of 1000 microns with a length of 4-5 meters was used immediately after the relaxation pond. Each of these systems consisted of three repetitions and their use lasted from the beginning to the end of the rearing period (Fig.3).

Figure 3: Three-row filtration system with 1000, 500 and 250 micron.

We collected the number of unwanted creatures trapped in both nets daily to evaluate their performance. Finally, information was collected and recorded from the shrimp processing centers at the end of the farming period. The significance of the differences was measured using SPSS 24 statistical software, one-way analysis of variance (ANOVA) and Tukey's test with a confidence level of 95% at the end of the study. Diagrams were created using EXCEL 2013.

Results

The population of unwanted species in the study area also differed based on the season and duration of spawning. Nevertheless, the results showed that most unwanted species spawned between May and June and sometimes until the end of August in the Delvar region. In this study, several species of fish, crustaceans and jellyfish were found, including milkfish (*Chanos chanos*), *Liza klunzingeri*, *Anodontostoma chacunda*, *Terapon puta*, *Sillago japonica*, Arabian toothcarp (*Aphanius* sp.), blue crab (*Callinectes* sp.), black crab or mangrove crab or mud crab (*Scylla* sp.), Hermit crab, jellyfish, *Meteorappleaeus affinis*, *Penaeus semisulcatus* (green tiger prawns) (Table 1) (Figure 4).

Table 1: Different species of aquatic species in the irrigation water channel of shrimp farming complexes and their spawning season.

Unwanted species	Egg diameter (micron)	Spawning season		
		The highest rate of spawning		The lowest spawn rate
Aphanius sp.	1187-1293	First of May	End of June	July to August
Terapon puta	1380-1700	First of May	End of June	July to August
Chanos chanos	1100-1200	First of May	End of June	July to August
Sillago japonica	180-710	First of May	End of June	July to August
Liza klunzingeri	40-750	First of May	End of June	July to August
Anodontostoma chacunda	19-950	First of May	End of June	July to August
Metapenaeus affinis	290-300	First of May	End of June	July to August
P. semisulcatus	290-300	First of May	End of June	July to August
Blue crab	100-250	First of May	End of June	July to August
mud crab	100-300	First of May	End of June	July to August
Hermit crab	10-61	First of May	End of June	July to August
jellyfish	60-230	First of May	End of June	July to August

Figure 4: Aquatics in the irrigation channel of shrimp farming complexes. A: Blue crab. B: *Metapenaeus affinis*

Also, in each two filtration system, there was no significant difference in the number of unwanted objects and organisms trapped before micron filters (filtration systems) (Table 2) (p>0.05).

Table 2: Objects and unwanted organism trapped in different parts of the farm water intake system

Position	Mesh hole (mm)	Unwanted objects and creatures	Amount (kg)
Suction basin mesh	10-20	Algae mud and mud, oysters and big fish, floating objects in the water channel, jellyfish, macro-algae	200 - 300 during one period
Mesh around the valve	10-20	Algae mud and mud, oysters and big fish, floating objects in the water channel, jellyfish, macro-algae	300 - 400 during one period
net under the sand filter (relaxation pool)	10	Algae mud and mud, oysters and big fish, floating objects in the water channel, jellyfish, macro-algae	1000 - 1500 during one period
Mesh after sand filter	5	Fish pieces, seaweed, small fish, shrimps and crabs, small black crab, macro-algae	About 2-3 every two hours

While the result of comparing the newly designed filtration system with the old system indicated that from May to September, each of the micron nets was placed in different rows, were able to prevent entering different objects such as clams, floating algae, eggs and larvae related to fish and or wild shrimp and different aquatics. The amounts and types of these objects and organisms were different depending on the mesh`s pore in different rows.

Based on the results of this study, the number of unwanted organisms trapped from May to September was different in each of the micron nets placed in the different rows of the three-row filtration system. On the other hand, due to the use of a 250-micron net in the third row, an enormous amount of aquatic eggs and larvae were trapped, especially in May and June (Figure 5). Nevertheless, the amounts trapped in these nets decreased significantly between July and September.

Figure 5: Collecting aquatic eggs in the 250-micron mesh of the third row of the three-row filtration system.

In addition, fish larvae, shrimps, and crabs were mostly trapped in the second-row nets with 500-micron holes. However, a high number of unwanted creatures trapped mainly between May and June. But, these values gradually decreased until September. The daily performance of 1000 micron nets in the first row indicated that the number of unwanted organisms captured in this row did not significantly differ during other months (Table 3)

Table 3: Unwanted organisms trapped in different sections and months of the three-row filtration system.

Row		First	Second	Third
Mesh hole (Micron)		1000	500	250
Month	**Kind of unwanted organisms**	**Big fishes, big other shrimps, big and small crabs, pieces of oysters and jellyfish and objects floating in the water.**	**larvae of fish, shrimp and crab**	**Eggs and larvae of fish, shrimp and crab**
May	Approximate amount (grams) per nets	180-200	250-300	500-1000
June	Approximate amount (grams) per nets	180-200	250-300	500-1000
July	Approximate amount (grams) per nets	180-200	150-200	300-500
August	Approximate amount (grams) per nets	180-200	120-180	200-400
September	Approximate amount (grams) per nets	180-200	70-100	150-300

In farms with one-row filtration system, were trapped only large fish, juvenile other shrimp species, large and small crabs, oysters, jellyfish, algae filaments, and floating objects in the water during different months. These systems did not trap aquatic eggs or larvae (Table 4).

Table 4: Unwanted organisms trapped in different months of the one-row filtration system.

Row		First
Mesh hole (Micron)		1000
Months	**Kind of unwanted organisms**	**Big fishes, big other shrimps, big and small crabs, pieces of oysters and jellyfish and objects floating in the water.**
May	Approximate amount (grams) per nets	180-200
June	Approximate amount (grams) per nets	180-200
July	Approximate amount (grams) per nets	180-200
August	Approximate amount (grams) per nets	180-200
September	Approximate amount (grams) per nets	180-200

Nevertheless, there was a significant difference in trapped objects in three-row filtration systems compared to one-row systems during farming. The cause of this difference was due to the higher amount of things trapped in three-row filtration systems (Table 5).

In shrimp ponds that used a one-row filtration system with a mesh of 1000 microns during the study period, the investigation of unwanted organisms revealed that due to the lack of obstruction for aquatic larvae and eggs to enter and or the rupture of nets, especially during the first months, a variety of aquatic species were able to enter the shrimp ponds, including wild fish, juvenile wild shrimp, blue crabs, and jellyfish (Fig. 6).

Table 5: Comparison of the mean ± standard deviation of the total number of unwanted organisms trapped daily in each of the different filtration systems in different months (dissimilar letters in each row indicate the significance and similar letters indicate non-significance).

Filtration system	Months	Three-row	One-row
Total (gram)	May	6197.08±7.24^{a}	169.95±1.95^{b}
	June	1172.26±2.33^{a}	175.98±0.89^{b}
	July	744.34±2.34^{a}	174.21±2.34^{b}
	August	650.61±1.38^{a}	180.43±1.26^{b}
	September	484.67±0.32^{a}	177.55±0.26^{b}

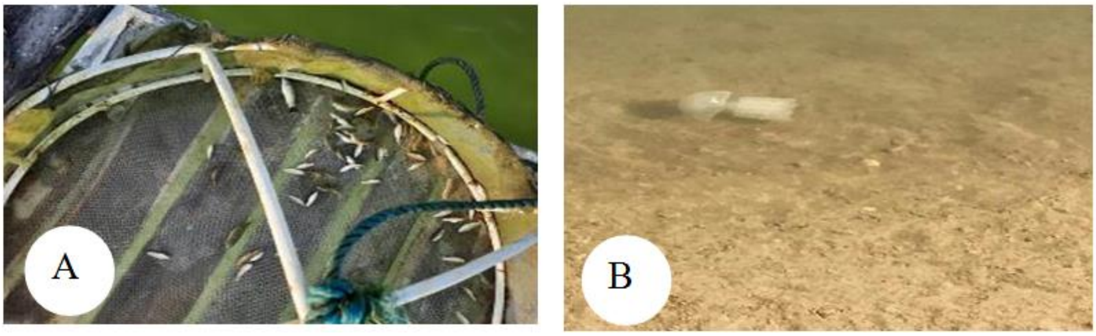

Figure 6: Unwanted organisms in shrimp ponds. A: *Aphanius* sp. B*:* jellyfish.

The survey conducted in the shrimp processing centers showed that the amounts of unwanted organisms collected from the farms that used the three-row system were significantly lower than the one-row system (p<0.05). Also, If the farms had stored post-larvae in May to June, the amount of unwanted would be significantly higher than in July (p<0.05) (Fig. 7).

Table 6: Amounts of unwanted organisms collected from different treatments in processing centers.

Filtration system	*Kind of unwanted organisms*	Stocking time	
		May (kg)	June (kg)
Three-row	Other shrimp species	5-10	4-7
One-row	Other shrimp species	500-700	250-500
	Wild fish	1000-1500	700-1000
	Crustacean	20-30	15-20

Figure 7: Collection of different species of wild fish in shrimp processing centers

Based on the results of the study, the production indicators of production tonnage, feed conversion rate (FCR), and survival rate of farms with one-row water filtration systems (1000 microns) were significantly lower than those with three-row systems ($p<0.05$) (Table 7).

Table 7: Comparison of mean ± mean standard deviation of the production indices of different filtration system (dissimilar letters in each column indicate significance and similar letters indicate non-significance).

Filtration system	Production range (tons)	Average production (tons)	Feed conversion rate (FCR)	Average of FCR	Survival rate (%)	Average percentage of survival rate	Food consumption (tons)
Three-row	80-85^{a}	82.5±0.67^{a}	1.5-1.6^{a}	1.55±0.02	85^{a}	82.5±0.54^{a}	120-150
One-row	45-50^{b}	47.2±0.55^{b}	1.7-1.8^{b}	1.75±0.05	60^{b}	61.6±0.56^{b}	120-150

Furthermore, the one-row filtration system was associated with the highest percentage of unwanted organisms, while the three-row filtration system was associated with the lowest percentage (Table 8).

Table 8: Comparison of the percentage of unwanted items in each of the different filtration systems (dissimilar letters in each row indicate significance and similar letters indicate non-significance).

Filtration system	Three-row	One-row
Percentage	0.01^{a}	2^{b}

The income from selling unwanted creatures was very low compared to the cost of selling shrimp because unwanted creatures were very low in value (Table 9).

Table 9: Income from the sale of unwanted organisms collected from different filtration systems.

Filtration system	Other shrimp species ($)	Wild fish ($)
Three-row	1.67	0
One-row	167	1000

*Each dollar is equal to 300,000 IRR.

Also, the amount of production decreased by 1300-2400 kg/ ha on farms using the one-row filtration system compared with farms using the three-row filtration system (Table 10).

Table 10: Comparison of production in kg/ha in different filtration systems (different letters in each row indicate significance and similar letters indicate non-significance).

Filtration system	Three-row	One-row
kg/ha	5300-5700^{a}	3000-3300^{b}

In the farms that used one-row filtration systems, the economic loss was significantly higher than that of the farms that used three-row filtration systems due to decreased shrimp production and increased food costs due to unwanted organisms' consumption of food (Table 11).

Table 11: Comparison of mean ± standard deviation of losses caused by food consumption by unwanted organisms, lack of sale of shrimp due to reduced production in the farm and total losses in different filtration systems (unlike letters in each column indicate significance and similar letters indicate non-significance).

Filtration system	Food consumed by unwanted (kg)	Economic loss due to consumed food ($)	Economic loss due to not selling shrimp ($)	Incurred losses ($)
Three-row	5-10[a]	8.33[a]	41.67[a]	48.67[a]
One-row	2500-3000[b]	2500[b]	8000[b]	10500[b]

*Each dollar is equal to 300,000 IRR

Discussion

In recent years, it has been observed that the occurrence of diseases in shrimp farms is always considered one of the factors of industry stagnation. It is possible to prevent the spread of disease by creating physical barriers in shrimp ponds to prevent the entry of pathogenic agents. Quicksand filters are one method of dewatering shrimp farms based on the tidal system. In shrimp farms, these systems had been associated with many problems, including the entry of unwanted crustaceans such as crabs, other shrimp species, wild fish, and other aquatic organisms, due to the lack of proper water filters (Yap and Landoy, 1993).

Due to the importance of water in aquaculture, other studies have shown that today various systems are used, including multi-row water filtration systems and filter drum-based filtration systems (Biao *et al*., 2009). The water raceway system is one of the aquaculture systems. The sedimentation or storage ponds are an essential part of this system. These ponds occupy 20-25% of the rearing ponds on farms. This system transfers farming pond water to seawater storage ponds and then to the wastewater section through channels. As a result, disease spread has decreased drastically in this system because of the decline in water exchange (Taw, 2014). Unfortunately, due to the design of the shrimp farming complexes in Bushehr province, none of the farms have water storage and preparation ponds. Therefore, seawater enters these farms' farming ponds directly without disinfection or preparation. One of the solutions to prevent the occurrence of diseases on farms is to create physical barriers to prevent the entry of pathogens and their carriers into breeding ponds.

Therefore, since 2004, after the outbreak of white spot virus disease in Bushehr province, the use of 1000-micron mesh after the sand filter has been required. According to undocumented reports, the above system effectively prevented large unwanted species such as wild fish and other shrimp species enter to shrimp ponds, but this way was unable to prevent the entry of eggs or aquatic larvae into shrimp ponds. On the other hand, due to the blocking of the 1000-micron mesh holes by the mud suspended in the water and the tearing of the mesh, many unwanted creatures such as small crabs, wild fish and migratory shrimps entered the pond. As a result of the entrance of unwanted organisms into shrimp rearing ponds, as well as the increase in food competitors and predators in the ponds, farmers face the entry of vectors carrying pathogenic agents (Primavera, 1992). Therefore, to prevent the occurrence of diseases in shrimp farms and existing problems since 2019, according to instructions provided by the country's veterinary organization under the strategic program for the white spot syndrome disease, shrimp farms were required to use micron nets with three-row filtration systems (Veterinary Organization, 2019). This system was associated with various issues in its early years, such as a lack of proper water filtration and the time-consuming nature of filtration, which sometimes farmers had to remove. Therefore, the design of a standard filtration system with high efficiency can be associated with improving productivity and increasing profitability, in addition to preventing disease on the farm. The results suggested that a 1000 micron mesh one-row filtration system could only prevent the entry of unwanted organisms such as wild fish, other shrimp species, oyster pieces, filamentous algae, and floating objects in the water. Hence, the total amount of organisms collected in this system's nets from the beginning to the end of the rearing period daily was 180-200 grams. Also, the results obtained from the processing centers also indicated that there was an increase in unwanted organisms, such as wild fish and other shrimp species, due to did not prevent the entry of aquatic larvae and eggs during the farming period. While the comparison of the results of three-row filtration systems indicated that this system more effectively prevents unwanted entry into shrimp ponds. Pazir *et al*. (2017) reported that using a three-row filtration system could prevent the entry of pathogenic agents into breeding ponds. According to the obtained results, it was observed that the nets with 250-micron holes in the three-row filtration system could prevent the entry of a large portion of aquatic eggs and larvae into farming ponds. As you know, from the first of May to the end of June, there is the highest spawning rate of wild fish and other shrimp species, such as *Metapenaeus affinis* and *P. semisulcatus*, throughout the central water canal of Bushehr shrimp farming complexes. Since the season spawning of unwanted organisms coincides with shrimp post larvae stocking time in farms, this three-row filtration system can significantly reduce the entry of these organisms into the ponds.

Conclusion

As mentioned, the unwanted entrance of crustaceans and other aquatic into farming ponds can both as food competitors and result in the transmission of pathogenic agents because they are carriers of pathogens. As a result, the three-row filtration system with nets of 1000, 500, and 250 holes is more efficient in removing unwanted objects such as aquatic eggs and larvae than the one-row system. Also, based on the amount of waste collected in shrimp processing centers after harvesting, this issue is confirmed. The results of the production indicators showed the amount of production decreased by 1300-2400 kg/ha, and the production costs (costs related to the purchase of food) increased in farms that used a one-row filtration system. Consequently, their profitability had been greatly reduced compared to the farms with the three-row filtration system. On the other hand, because unwanted organisms are carriers of pathogens, if their numbers increase in farming ponds, it can be associated with an increase in the spread of disease on the farm. Finally, if shrimp farming aims to improve productivity and reduce disease risks. Through the rearing process, farmers should use a combined filtration system that includes sand filters and three-row filtration with springs of 1000 (in the first row), 500 (in the second row) and 250 (in the third row) microns. Therefore, they can prevent unwanted organisms from entering the breeding ponds by purifying the farm's water.

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