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Mechanization impact of improvement of some quality indicators of wastewater in rainbow trout culture dual-purpose farms in Markazi Province of Iran

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Abstract

The most important goals of mechanization in aquaculture are to reduce the production costs and improve profitability, reduce production risk, observe health and prevent diseases, and observe environmental aspects in production, improving quality of farm effluents and proper nutritional management leading to higher level of productivity. This research was conducted aiming at investigating the efficiency of mechanization on quality of wastewater in dual-purpose rainbow trout culture farms in Markazi province of Iran. 30 dual-purpose rainbow trout culture farms with high production capacity and more ponds located in 5 cities of the Markazi province were selected and their mechanized tools were determined. The physical and chemical factors of inlet and outlet water, including dissolved oxygen, pH, nitrite, ammonia, nitrate, phosphate and total suspended solids were measured. Although water factors of most of the studied farms were acceptable for raising rainbow trout, various variables such as amount of production, health management, quality and quantity of washing ponds, output and discharge improper pools, failure to use siphons between two outlets, failure to implement fishing patterns, improper siphonage and drainage are effective in farm performance and disrupt the balance of physical and chemical factors of water and challenged the efficiency of mechanized devices and equipment used in the farms.

Keywords: Mechanization, Dual-purpose Farms, Rainbow trout, Outlet, Inlet, Markazi Province

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Introduction

Aquaculture, providing about half of the world's fish production, plays an important role in providing seafood, reducing malnutrition, hunger and poverty (FAO, 2010). Since fishes are considered as a good source of protein and an income product, with the increase in population, the demand for fish consumption has increased, followed by the creation of fish culture ponds (Bhatnagar and Devi, 2013).

Dual-purpose pools are pools that have been built in advance to store water for agricultural activities, and the technical principles of fish culture have not been observed in these pools, but with measures such as pool modification, installing nets and valves at the entrance and exit, it can be prepared for fish culture (Nafisi *et al*., 2001; Alizadeh *et al*., 2007). The limitation of water resources in the country and the need of people for healthy protein materials has caused the dual or multi-purpose use of small water resources (springs, agricultural canals and wells) as well as fish production in order to meet people's needs and strengthen the economic base of villagers and farmers (Nafisi *et al*., 2001).

In general, it is necessary to increase aquaculture production from one million tons in 1953 to more than 200 million tons in 2050 along with environmental protection (Avnimelech, 2009). On the other hand, considering the advantages of aquaculture and the production of various food and protein sources and their effect on the development of human societies and creating economic benefits, scientific communities seek to provide solutions to reduce the negative effects of aquaculture (Porchas and Martinez-Cordavo, 2012).

Food production activities, including the aquaculture industry, affect the environment like any other human activity. Effluent from aquaculture systems may cause changes in the ecosystems receiving the effluent. The share of environmental effects of aquaculture in the world is small compared to other human activities such as agriculture, industry, housing construction, etc. (Pillay, 1990; Ackefors and Enell, 1994). Trout production in the country, as one of the largest sub-sectors of aquaculture, has placed Iran in the top ranks of the world.

Since the cultivation of this fish has targeted the highest quality water resources in the semi-arid country of Iran, paying attention to the responsible development of aquaculture (in contrast to purely economic development) by using advanced systems and mechanization, not only in optimizing Water consumption in this area and increasing the quantity and quality of fish production is effective, but it also minimizes environmental risks and ensures the sustainability of production (Hafezieh and Mateenfar, 2013). Mechanization literally means the use of a machine as a substitute or complement to human labor. This definition has been promoted in agriculture and natural resources and is known as the concept of proper management of resources, inputs, machines and tools, with the aim of

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reducing production cost and increasing the quantity and quality of the product (Almasi *et al.*,2001, Behrouzi Lar, 2001, Bagheri, 2006).

The development of aquaculture depends on various factors, and as a result, each of these factors has caused bottlenecks in the way of development. The factors of lack of easy access to water, suitable land, favorable climatic conditions and seasonal changes in the quantity or quality of available water have caused problems in the development of rainbow trout farms with conventional methods in many areas. In order to deal with these issues, the desire of aqua-culturists to increase the density of cultivation and reduce the amount of water consumed, and even to cultivate aquatic animals in places with low water or in drought crises, researchers have to design and build a variety of mechanical purification systems and use devices and methods and aeration have encouraged (Hedayati, 2005). This research was conducted with the aim of investigating the effect of mechanized equipment used on the improvement of water quality indicators of selected dual-purpose farms in 5 cities of Markazi Province, Iran.

Materials and methods

The present research was conducted in 30 dual-purpose agricultural farms located in 5 cities of Markazi Province namely Farahan (6 farms-numbers 1 to6), Arak (11farms-numbers7 and 21 to 30), Khondab (3 farms-numbers 15 to 17), Shazand (7 farms-numbers 8 to14) and Khomein (3 farms-numbers 18 to 20) in 1400. In order to investigate the effect of mechanized tools on the effluent quality of selected farms under study, during field visits, the presence of aeration tower, drum filter, the number and type of aeration devices were recorded in the farms. Then, samples were taken from the water inlet and outlet of the selected farms. For this purpose, the water samples to measure the amounts of nitrate, ammonia phosphate and nitrite were first fixed on the spot with 98% sulfuric acid (Merck) and then they were transferred to the laboratory in ice freezers in the temperature range of 3-4°C. The physical and chemical parameters of water that were measured based on the 2005 standard method at the entrance and exit of farms (Franson, 2005) are:

Dissolved oxygen: O_2 by membrane electrode method with Multi 3410 WTW multimeter, pH: by electrometry with portable pH meter 340 i WTW, nitrate (NO_3^-): by ultraviolet spectrophotometry with T +80 spectrophotometer, nitrite (NO_2^-): by colorimetric method with spectrophotometer model + 80 T, phosphate ($PO4_3^-$): by tin chloride method with spectrophotometer model + 80 T, ammonia (NH_3): by Nessler method (Franson, 2005) with spectrophotometer + 80 T model, total suspended solids (TSS): were read by drying method at 103°C.

Results

Equipment and mechanization tools used in the studied farms are given in Table 1. Also, Changes in the input and

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output factors of water in selected farms of Markazi Province are shown in Figures 1-7.

Table 1: equipment and mechanization tools used in the studied farms.

farm No.	Sedimentation pool	sorting	drum filter	No. of air conditioner	air tower
1	-	-	-	8	+
2	+	+	-	8	+
3	+	+	-	12	+
4	-	+	-	9	+
5	+	-	+	10	-
6	-	+	-	8	+
7	-	+	-	12	+
8	-	+	+	3	-
9	+	+	-	15	+
10	-	+	-	18	+
11	-	+	-	10	+
12	+	+	+	11	+
13	-	+	+	3	+
14	-	+	-	15	+
15	+	+	-	9	+
16	+	-	+	7	+
17	+	-	-	6	+
18	+	-	-	17	-
19	+	-	-	4	+
20	+	+	+	8	+
21	+	-	-	5	+
22	+	+	-	23	+
23	-	+	-	13	+
24	-	+	-	6	+
25	-	+	-	12	+
26	+	+	-	12	+
27	+	+	-	20	+
28	-	+	-	11	+
29	+	+	+	11	+
30	-	+	-	13	+

The comparison of the results of the inlet water of the farms showed the amount of dissolved oxygen in the inlet with a minimum of 5.59 mg/liter in farm 1 and a maximum of 9.39 mg/liter in farm 24. The comparison of the results of the output water of the farms showed the amount of dissolved oxygen in the

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output with a minimum of 5.76mg/liter in farm 15 and a maximum of 9.25 mg/liter in farm 1.

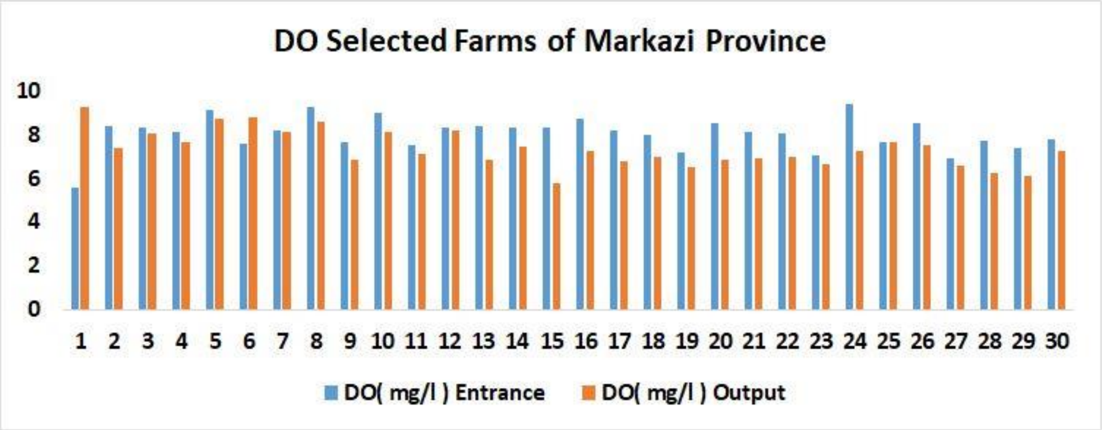

Figure 1: Changes in the input and output dissolved oxygen of selected farms in Markazi Province.

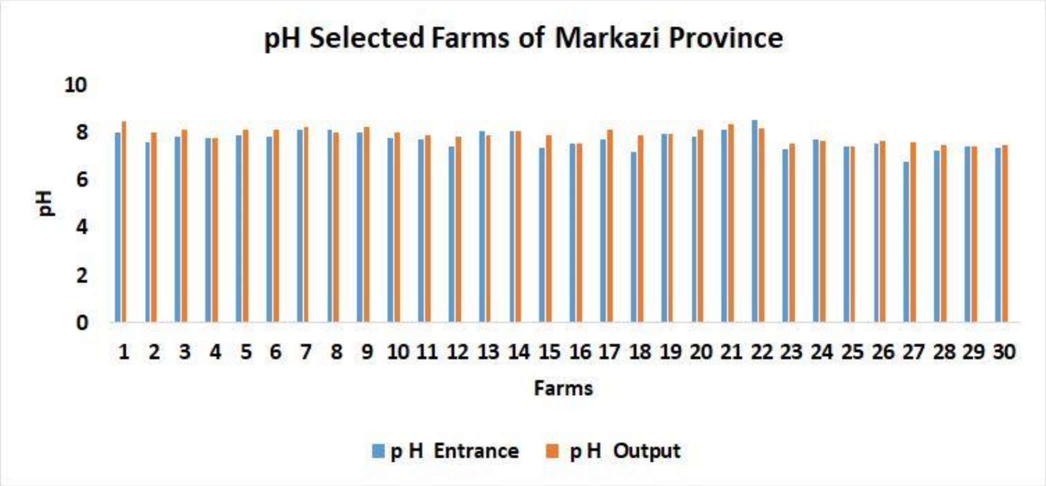

Figure 2: Changes in input and output pH of selected farms in Markazi Province.

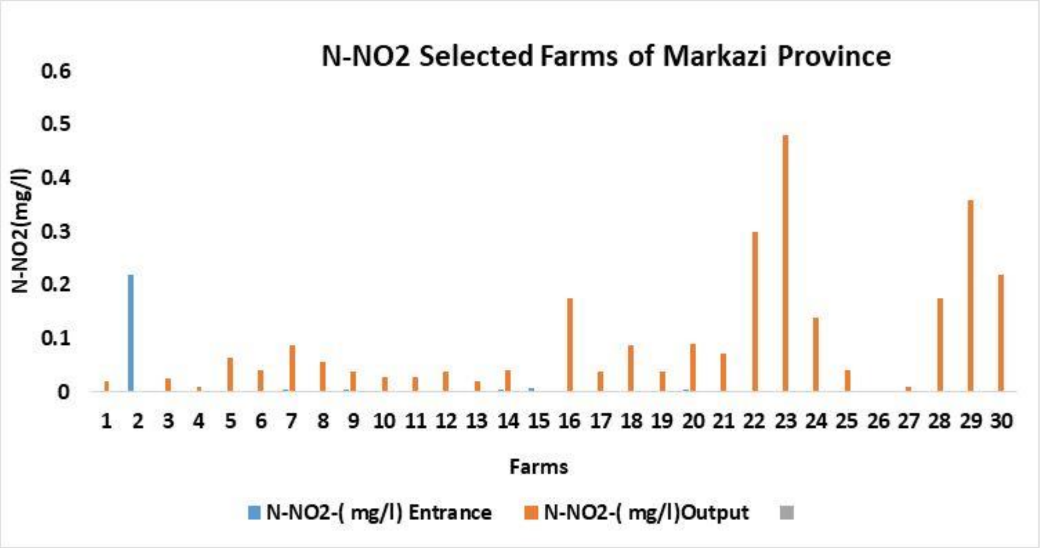

Figure 3: Changes in the input and output nitrogen nitrite of selected farms in Markazi Province.

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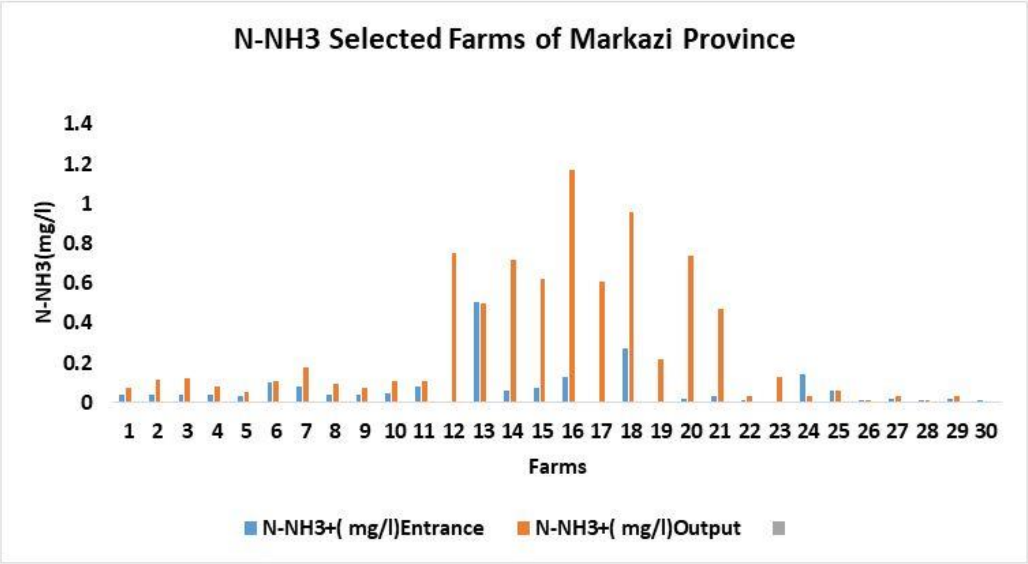

Figure 4: Changes in the input and output ammonia nitrogen of selected farms in Markazi Province.

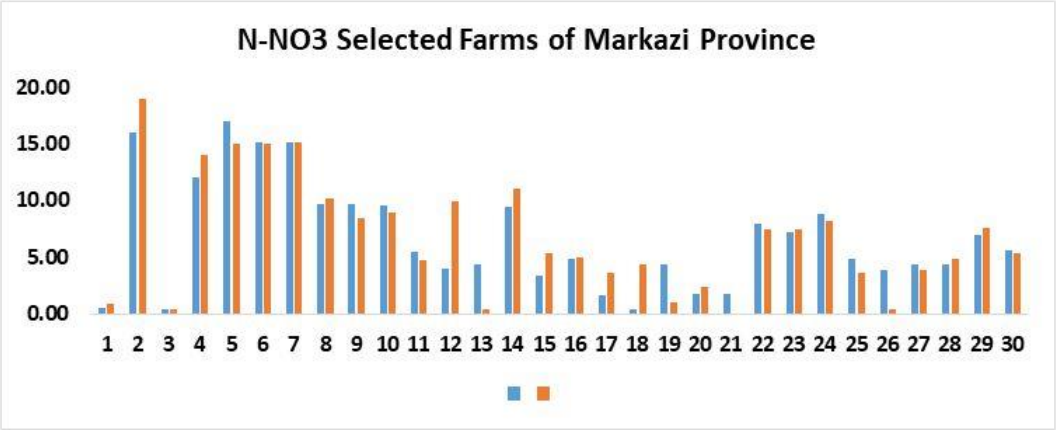

Figure 5: Changes in the input and output nitrogen nitrate of selected farms in Markazi Province.

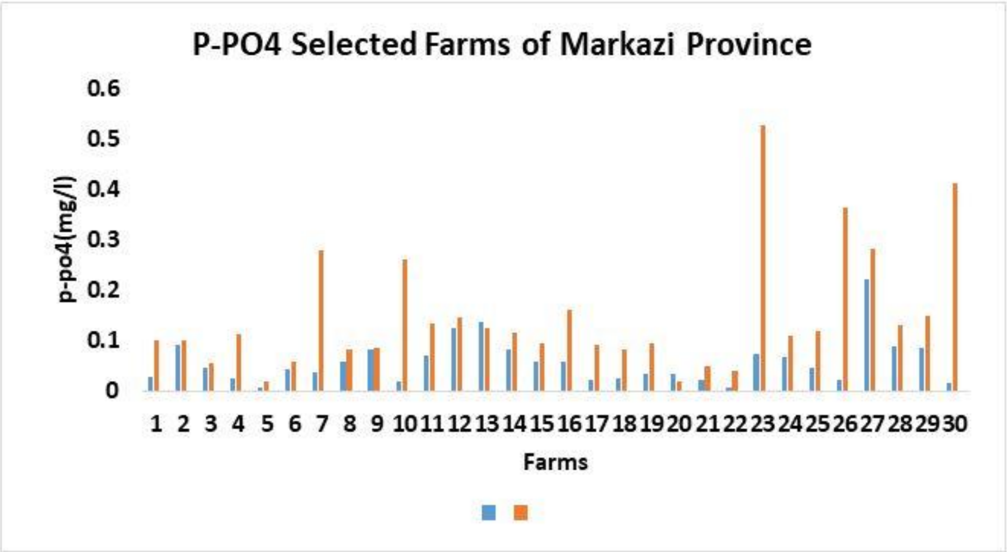

Figure 6: Changes in the input and output phosphorus and phosphate of selected farms in Markazi Province.

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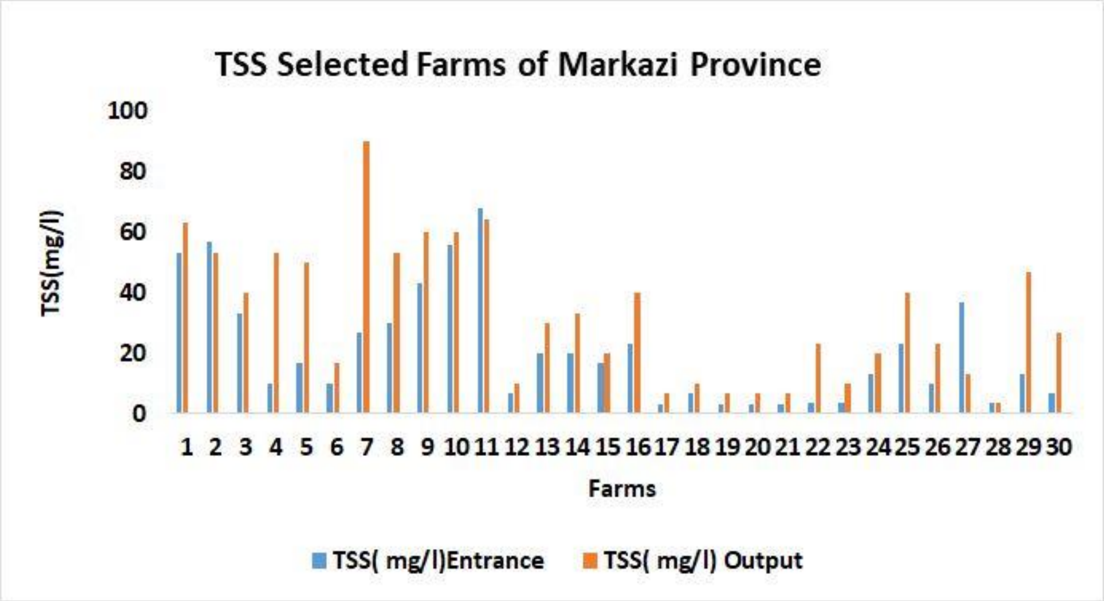

Figure 7: Changes in the input and output total suspended solids of selected farms in Markazi Province.

The comparison of the results obtained from the inlet water of the farms showed that the pH level at the inlet was less than 6.8 in farm 27 and the value was 8.56 in farm 22. The comparison of the results obtained from the output water of the farms showed that the pH level in the output was at least 7.4 in code 29 and the value was 8.47 in farm 1.

The comparison of the results of the input water of the farms showed the amount of nitrogen nitrite in the input with a minimum of 0 mg/liter in farm 14 and a maximum of 0.22 mg/liter in farm 2. The comparison of the obtained results of the output water of the farms showed the amount of nitrogen nitrite in the output with a minimum of 0.001 mg/liter in farm 2 and a maximum of 0.48 mg/liter in farm 23.

The comparison of the results of the inlet water of the farms showed the amount of ammonia nitrogen in the inlet with a minimum of 0 mg/liter in farms 19 and 23 and a maximum of 0.505 mg/liter in farm 13. The comparison of the obtained results of the output water of the farms showed the amount of ammonia nitrogen in the output with a minimum of 0 mg/liter in farm 30 and a maximum of 1.17 mg/liter in farm 16.

The comparison of the results of the input water of the farms showed the amount of nitrate nitrogen in the input with a minimum of 0.33 mg/liter in farm 4 and a maximum of 16 mg/liter in farm 2. The comparison of the obtained results of the output water of the farms showed the amount of nitrate nitrogen in the output with a minimum of 0 mg/liter in farm 22 and a maximum of 19 mg/liter in farm 2.

The comparison of the results of the input water of the farms showed the amount of phosphorus phosphate in the input with a minimum of 0.006 mg/liter in farm 23 and 6 and a maximum of 0.221 mg/liter in farm 28. The

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comparison of the obtained results of the output water of the farms showed the amount of phosphorus phosphate in the output with a minimum of 0.019 mg/liter in farm 21 and a maximum of 0.528 mg/liter in farm 24.

The comparison of the results of the farm inlet water showed the total amount of suspended solids in the inlet with a minimum of 3.3 mg/liter in 7 farms and a maximum of 68 mg/liter in code 11. The comparison of the results of the output water of the farms showed the total amount of suspended solids in the output with a minimum of 3.3 mg/liter in farm 28 and a maximum of 90 mg/liter in farm 7.

Discussion

Aquaculture is essential to increase economic growth in urban and rural areas by creating jobs and income. However, attention should be paid to the production methods to reduce the negative effects of the production process (Midlen and Redding, 1998; Read *et al.,* 2001). In fish breeding ponds, water plays the most important role in nutrition, reproduction and life cycle of fish (Brönmark and Hansson, 2005). Water quality in fish ponds is often affected by the reaction of physical and chemical compounds and can have potential effects on pond production and fish health (Akoma *et al.,* 2014). Determining the physicochemical parameters of fish farm effluents that are released into water sources and the impact of aquaculture on these parameters provides basic information for the regulation of environmental protection. Based on this information, fish farmers will be required to develop farm wastewater treatment systems and improve environmental conditions in water sources (Pulatsu *et al.,* 2004). According to the standard, the optimal limit of dissolved oxygen for culture of cold-water fish is more than 5 mg/liter (Faeed *et al.,* 2019).

In this study, all farms were within the acceptable range of dissolved oxygen (5 mg/L) of the inlet water for rainbow trout. In all farms, the amount of this index in the output was within the acceptable range and in some cases, it exceeded the normal ranges for the output water of rainbow salmon culture ponds. Except for farms 1 and 6, in the rest of the farms, the output oxygen of the farm has decreased compared to the input. The increase in oxygen in the output of the two farms can be due to the metabolic activity of the fish and the decrease in the density of fish in the ponds (Farzi *et al.,* 2022). The decrease in oxygen output compared to the input of most of the studied farms can be explained by the increase in production, nitrogen, phosphorus, suspended matter and pool bottom sediment (SobhanArdakani *et al.,* 2014).

Also, the increase in waste materials of fish culture ponds (mainly containing organic matters) can be one of the reasons for the decrease of dissolved oxygen in the output of farms (Tavakol *et al.,* 2020). In general, oxygen in the water decreases with the increase in the number of fish due to the consumption of oxygen by the fish and some decomposition reactions in the outlet)

(Wedemeyer, 1996). This is in accordance with the study of Varedi *et al.* (2010) which indicated a decrease in the concentration of oxygen in the output of rainbow salmon farms compared to the input. Also, the amount of dissolved oxygen in the input water of the farms, except for farms 1 and 6, was 2.5-1.5 mg/liter higher than the output water. The issue is consistent with the opinion of Shepherd and Bromage (1992), stated that the amount of dissolved oxygen decreases from 2 to 3 mg/liter when water passes through a pool.

In the comparative analysis of the dissolved oxygen index of the inlet and outlet water, the impact of 8 splash devices, 1 air tower device in farms 1 and 6 is evident, so that the increase of this index has been met with (3.6 mg/liter). Except for farms 1 and 6, in other farms, no significant difference was observed in the dissolved oxygen of the inlet and outlet water. This discrepancy in the position of using the aerator and mechanization equipment in the farm, can be related to the mismatch of the functional power of the device with the actual needs of the farm.

pH has a direct (concentration of acidic or basic ions) and indirect (conversion of ammonium to ammonia and dissolution of toxic substances in water) effect on aquatic life (Naderi Jelodar *et al.*, 2006). Fish density increases the rate of respiration and decreases the pH, but the pH increases with the increase of photosynthesis (Millero and Sohn, 1992). On the other hand, in high density, excreta increase and indirectly causes pH changes (Moyle *et al.*, 2012). According to the standard, the optimal pH level for the culture of cold-water fish is 6.5-8.5 (Faeed *et al.*, 2019).

In the present study, except for farms 8, 13, 19, 22, 24, 8 and 29, the pH in the output increased compared to the input, and this increase was within the standard range of 6.5 to 9.5 for fish farming (Boyd and Gautier, 2000). Various researchers also reported an increase in pH in the output of fish farms (Teodorowicz *et al.*, 2006; Sarkhosh *et al.*, 2016). The decrease in pH in the output of farms is in accordance with studies of Bonaventura *et al.* (1997) and Boyd (2003).

Inorganic nitrogen is available in fish breeding ponds in the form of ammonia, nitrite and nitrate, nitrite is less toxic than ammonia and nitrate has the lowest toxicity, and its concentration in culture ponds is usually very low (Asha and Muthiah, 2005). For each kilogram of dry pellet food consumed in salmon breeding ponds, on average 30 to 60 grams of nitrate is produced in the pond, which can be converted into toxic nitrite under certain conditions (Shepherd and Bromage, 1992).

Also, nitrite is produced in fish culture ponds due to the nitrification process from ammonia (Campbell, 1999). In fish farms, the amount of nitrite and nitrate increases with the growth of fish and the increase in activity and consequently the increase in suspended matter (Kaeidi *et al.*, 2018). Lawsen (2001) stated the permissible limit of nitrite for breeding rainbow salmon as 0.39-0.19 mg/liter. According

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to the mentioned standard, the input of all farms was at the optimal level, but the output of some farms was slightly higher than the standard. According to the mentioned standard, the input of all farms was at the optimal level, but the output of some farms was slightly higher than the standard. In the present research, except for farms 2 and 15, in the rest of the farms, the amount of output nitrogen nitrite has increased compared to the input. The increase of nitrite nitrogen in the outlet is in accordance with the results of the study (Loch *et al.,* 1996, Selong and Helfirich, 2002; Farzi *et al.,* 2022). The reduction of nitrite nitrogen in the output of farms 2 and 15 can be due to the optimal use of mechanical aerators and physical water purification (Nekuie Fard *et al.*, 2013). Also, low production and correct management and compliance with standards can be factors involved in setting the level of nitrogen nitrite at the optimal level.

Ammonia toxicity is dependent on the amount of ammonium nitrogen, pH and temperature) (Colt *et al.*, 2009). The conversion of ammonium to ammonia accelerates at a pH above 9 and its toxicity increases. Lawsen (2001) Ammonia limit for fish farming 0.5 mg/L for rainbow trout, about 25 to 50 grams of ammonia is produced for every kilogram of dry pellet food consumed in trout culture ponds (Shepherd and Bromage, 1992).

In all farms, the amount of this index at the inlet was within the acceptable range, and at the outlet, in some farms, it was higher than the usual expected for the outlet water of rainbow trout breeding ponds. Except for farms 24, 13, 28, 30, in the rest of the farms, the amount of ammonia nitrogen in the output water has increased compared to the input. The reduction of ammonia in the effluent of farm 4 compared to the input can indicate the better performance of the mechanization and mechanical aeration system in the pools. In the current research, the amount of ammonia output increased compared to the input in most of the farms, which is in accordance with the study of Laird and Needham (1988), who reported that the amount of ammonia at the outlet point of fish farms increased compared to the inlet water, and it exceeded the recommended standard for fish farms by EEC. 0.1 mg/liter is more consistent (Laird and Needham, 1988).

In the studied pools, the highest pH level was 8.47, which can be a factor in reducing the harmful effects of ammonia toxicity in the breeding environment. Increasing the breeding activity of the pond, increasing the density of fish, using chemical drugs are effective factors in increasing ammonia in the output of farms (Farzi *et al.*, 2022). The increase of ammonia in the output of farms has been reported in the studies (Farzi *et al.*, 1402, Rahimibashar *et al.*, 2012) and it is consistent with the results of this research. These values have significantly increased in the output of the selected farms, which can be related to the amount of live fish mass per unit area, the intensity of fish feeding and the efficiency of the aeration device.

Various factors, such as agricultural fertilizers, industrial wastewater, and domestic sewage, increase phosphorus and nitrogen in rivers (EPA, 2013). The permissible limit of nitrate for rainbow trout farms is 16.9 mg/liter (Schwartz and Boyd, 1994, based on the standard of the optimal limit of nitrate for culture of cold-water fish, it is 4.52 mg/liter (Faeed *et al.*, 2019).

According to the mentioned standards, some farms had higher value both in the input and output, and some were in the normal range. In the present study, in some farms, nitrate nitrogen in the output increased compared to the input, and in some it decreased. One of the reasons that led to the reduction of nitrite and nitrate concentration between the inlet and outlet of the pools is the photosynthetic activity in the fish breeding workshop and also along the river course by aquatic plants (Hosseini *et al.*, 2013). Nitrate increase in output in the study (Hatami, 2008; Camargo *et al.*, 2011; Nabavi *et al.*, 2020). Also, in the study of Boaventura *et al.* (1997), no statistically significant difference was observed in terms of the amount of nitrate between different stations.

Nitrate in the effluent of some farms was measured in the range lower than the standard limit of discharge to the effluent (less than 50 mg/liter). In the farms where the amount of this index was measured higher at the output than the input, despite the presence of aerators, the effect of reducing this index was not observed in these farms. The factors such as the place of use, the amount of production per unit area and the maximum power of using the equipment during feeding can affect the amount of this index in breeding ponds. The general examination of this index showed a non-significant functional impact on its reduction in the use of mechanization equipment in some farms. But in some other cases opposite situation was observed. And the mechanization equipment had a reducing effect on the amount of this factor in the output compared to the input. In farm codes 21 and 26, according to the complete removal of nitrate nitrogen at the exit of the farm (farm 21 has 5 aerators including 3 splashes and the production rate is 6 tons, and farm 26 has 12 splash aerators and the production rate is 15 tons), this indicates that the use of this equipment in reducing this factor has a better performance.

Inorganic phosphorus is obtained directly from fish waste. Also, during the washing process in pools that contain uneaten food and fish feces, water soluble phosphorus increases (Brinker and Rosch, 2005). According to the standard, the optimal limit of mineral phosphorus for cold-water fish culture is less than 0.065 mg/liter (Faeed *et al.*, 2019). In this study, except for farms 13 and 20, in the rest of the farms, phosphate has increased in the output. Probably the effects of nutrients and organic substances (including metabolic substances and food residues) induced the phosphate increase (Wasielesky *et al.*, 2006).

Some farms had more phosphorus values in both input and output, and some were in the normal range. In general, high levels of phosphorus can be created by agricultural runoff, sewage, excessive use of animal manure, lack of proper management to have a proper diet, as well as the formation of a sludge layer in the pool due to the fertilizer remnants, food, plankton, fish feces and their decomposition and intense consumption of oxygen is due to the increase in the bacterial load of the pool floor (Delince, 1993). Carr and Goulder (1989) showed that the main reason for the increase in phosphorus can be due to the increase in wastewater and unused food output from the activity of fish farms, which is consistent with the results of the present research, except for farms 13 and 20.

For every kilogram of dry pellet food used in salmon breeding ponds, an average of 200 to 300 grams of suspended solids are produced in the pond (Shepherd and Bromage, 1992). According to the standard, the optimal limit of total suspended solids for breeding Cold-water fish is less than 80 mg/liter (Faeed *et al.*, 2019). According to the mentioned standard, except for the exit of farm 7, the rest of the farms were within the normal range both at the entrance and at the exit.

Also, except for farms 2, 11 and 27, in the rest of the farms, the total suspended solids in the output have increased compared to the input. The reduction of suspended solids in the outlet compared to the inlet can be due to the reduction of the slope and the reduction of the water speed, as well as the stagnation of water and the sedimentation of some suspended material inside the water transfer ponds, the use of sedimentation ponds before the water enters the breeding ponds and use from mechanical filtration (drum filter) in the field. On the other hand, its increase in the output compared to the input can be due to the presence of fish feces, uneaten food and other compounds. Other effective factors in increasing the total suspended solids in the output can be mentioned the time of feeding, washing of pools and harvesting. Installing a sediment pond before the breeding pond can be effective in reducing this problem.

The results related to the physical and chemical factors of water can only express the present state of the farm and various variables such as the amount of production, quantity and quality of food, size of food, flow rate and speed of water flow, health and nutritional management, food conversion rate, fish breed, density, weight of fish, the amount of excrement accumulated in the pond, the speed of feeding by the worker, the opportunity for the fish to eat while feeding, the time of feeding, the distance between feeding, water temperature, the rate of penetration of food at the height of the water, the way and amount of washing the pools. Improper outlet and drainage Pools, not using a siphon between two exits, the need for structural engineering based on the type plans provided by the fisheries organization, non-implementation of fishing patterns, improper siphonage and drainage are some of the variables which can be effective in farm performance,

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which can upset the balance of physical and chemical factors of water and challenge the efficiency of mechanized devices and equipment used in the farms. Therefore, it is necessary for researches in the future, to study the risk bottlenecks and obstacles to sustainable production of each farm separately and the specific version of that farm is prescribed in order to determine the efficiency of the equipment used according to the water quality of the farms.

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