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Impact of pollution caused by salmon breeding centers on river water quality

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ABSTRACT
The expansion of aquaculture and the need for its development in tandem with environmental criteria demonstrate this importance. Among these effects is the introduction of untreated sewage from salmon breeding centers into river water, which can negatively impact aquatic ecosystems. The present study was conducted to assess the impact of salmon breeding facilities on the Iraqi Euphrates River's water quality. The physical and chemical parameters of river water were measured at ten stations during the environmental surveys to determine the scope and limits of pollution changes. Six samples were collected from each station over one year, from January 2020 to January 2021. SPSS 23 software was used to conduct statistical analyses using analysis of variance (ANOVA) and Duncan's post hoc test. According to the ANOVA test's significant values, there was no statistically significant difference in the amount of TDS ($p < 0.05$). The remaining parameters sampled in different months exhibited significant differences ($p > 0.05$). Nitrate ($F = 67.12$), Phosphate ($F = 96.53$), DO ($F = 22.08$), BOD ($F = 6.81$), COD ($F = 17.48$) and TSS ($F = 32.92$) were determined to be the parameter values. The study's findings generally confirm the significant impact of fish breeding ponds on the quality of surface water resources. As a result, special attention should be prevent environmental complications through correct and principled aquaculture.

Keywords: Salmon breeding, Pollution, Water quality, Physical, Chemical.
Article type: Research Article.

INTRODUCTION
As a natural resource subject to a high concentration of human activity, rivers absorb a great deal of chemical and biological pollution (Kroglund *et al.* 2008). Due to the activity of bacteria and its reduction, the excessive entry of organic and carbonaceous substances in sewage and sewage into water body's results in the excessive consumption of dissolved oxygen (Kristensen *et al.* 2009). Among the solutions to improve and control the water quality of rivers are the control of pollutant sources at their source, aeration, and release of the flow, biological treatment, and so on. Pollution can enter the water from a variety of sources and routes (Rahbar *et al.* 2011). Water is considered polluted when the amount of foreign substances in it is sufficient to make its use hazardous (Quiñones *et al.* 2019). Investigating the process of environmental pollution and land destruction, as well as its consequences, such as global warming and climate change, has become increasingly important in recent years (Gholami *et al.* 2010; Burke *et al.* 2021). Diverse uses of river water resulting from the development of human

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societies and the expansion of industries have always contributed to the degradation of river water quality (Encina-Montoya *et al.* 2020). Since rivers are the only water sources that travel a considerable distance through cities, villages, and industrial and agricultural areas, river pollution can be viewed as an indicator of environmental pollution caused by human activities (Thorstad *et al.* 2021). Physicochemical and biological parameters determine the quality of river water (Kochalski *et al.* 2019). In addition to human resources, a significant amount of time is devoted to testing and analyzing chemical factors, which results in astronomical costs each year (Davidson *et al.* 2022). Management and quality protection of surface water resources has become an environmental challenge due to the expansion of human activities along riverbanks (Farabi *et al.* 2022). Compliance with the rules and standards regarding properly discharging the pollution load is viewed as a legal means of addressing this issue. There are two general approaches to the controlling and monitoring surface water quality (Hukom *et al.* 2020). In the conventional command control method, the legislative organization considers the amount of pollution load reduction at the output of all polluting sources, particularly a point, to be a default, and the excess discharge is subject to a fine (Hause *et al.* 2022). In environment-oriented standards, as opposed to command control methods, since monitoring and quality monitoring occurs at a specific point of the water body, conditions are created in which the proper amount of organic load discharge from polluting sources is determined by the self-purification capacity of the river and its location (Yilmaz & Koç 2014). Therefore, interaction and access to the most economical model for discharging the pollution load are possible (Koed *et al.* 2020). Typically, it is recommended to use decision-making algorithms to allocate wastewater and pollution load in conjunction with simulation models in an area to reduce the costs associated with the construction and operation of wastewater treatment facilities and maintain environmental standards (Compton *et al.* 2006; Varol 2019). A section of the Euphrates River has been chosen as the study area for this investigation. Human activities and environmental contamination have significantly impacted the river. For instance, the increase in the construction of residential houses and restaurants along the riverside and the direct discharge of sewage from residential houses and restaurants into the river contribute to its pollution (Meshesha *et al.* 2020). It increases the load of pathogenic and non-pathogenic microorganisms. Additionally, the disposal of waste and garbage in the vicinity of this river has not only resulted in a foul odor, but by directly discharging leachate into the river. It has disrupted the river's ecosystem, endangered the lives of aquatic animals, and eliminated bottom organisms or allowed resistant species to predominate (Saltveit *et al.* 2019). Fish hatcheries are among the most polluting sources in the Euphrates River basin. The quantitative and qualitative investigation of rivers is one of the most crucial factors that should be investigated. Since rivers are the most accessible water source required by various industries, they should be protected. Therefore, this type of study plays an essential role in the sustainable management of river ecosystems. It leads to identifying polluting sources and developing solutions to mitigate their adverse effects, thereby enhancing the quality of water resources. Therefore, the quality of the Euphrates River under the influence of salmon breeding centers was investigated in the current study. The investigation of different physicochemical parameters at different times is one of the novel aspects of the present study. Similar study has not previously been conducted in the area under study.

MATERIALS AND METHODS

The study area's topography, geology, hydrology, soil science, land use, and access roads were prepared and examined to carry out the sampling. The sampling stations were chosen based on natural conditions and access to the river, as well as natural and human effects such as the river's sub-branches, changes in geological structures, and polluting sources such as fish breeding ponds, agricultural lands, the establishment of residential centers, and existing industries. In general, the five criteria used in the station selection were: (i) before the connection of the side streams to the river and after that in the place where the water is entirely mixed, i.e., the exit and entrance of fish breeding ponds; (ii) before and after separation of a side stream from the river; (iii) places where a specific change occurs in the geology or soil of the area, and (iv) before and after the discharge of point pollutants (Maest *et al.* 2020). Several factors, such as the rate at which a pollutant creates a risk, the public's special concern and attention toward a particular pollutant, were considered when determining the order of importance for the examined parameters. In the environmental surveys, the physical and chemical parameters of the river water were measured at ten stations to ascertain the scope and limits of pollution changes. From January 2020 to January 2021, six samples were collected from each station over a one-year sampling period. The sampling was conducted using glass bottles. The sampling containers were washed with nitric acid and distilled water before being used.

Before transferring the samples to the laboratory, preparatory tasks such as stabilizing the samples with the necessary chemicals, determining the temperature of the air and water, and preparing the adhesive, including station specifications, sampling time, and weather conditions, were completed. The samples were transported to the laboratory under the appropriate temperature conditions and in the shortest time possible, where they were stored in the refrigerator until the test was conducted. Seven pollutant parameters, nitrate (N), phosphate (P), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and total suspended solids (TSS), were analyzed. Several physical and chemical parameters were measured on-site with portable measuring instruments. On specialized forms, the results of the field measurements were recorded. The information recorded on said forms pertains to the sampling day, including the sampling date and time, the weather condition, the source type, and the monitored station's code. The description related to the water samples prepared for shipment to the laboratory so that other parameters could be measured. Before performing the statistical analysis, the Kolmogorov-Smirnov test was used to examine the normality and fit of the data obtained from evaluating the studied parameters. After ensuring that the data had a normal distribution, analysis of variance (ANOVA) was used to compare the stations in terms of changes in the number of parameters. Duncan's post hoc test was also utilized in the following situations. It was assumed that the significance level was equal to 0.05, and SPSS 23 was used for calculations.

RESULTS AND DISCUSSION

Water quality analysis

In the current study, by selecting practical factors such as sampling point locations, water quality parameters, sampling periods, laboratory methods, and data analysis, it was hoped that the results would reveal the quality of the river in the study area and the sources of its pollution. Table 1 provides a statistical description (central indices and dispersion indices) of the sampling results and measuring the quality variables of river water in terms of physicochemical parameters over one year of sampling.

Table 1. Statistical characteristics of water quality parameters (units based on mg L^{-1}).

Parameter	Minimum	Maximum	Mean	Standard deviation
Nitrate	0.07	7.43	2.28	0.76
Phosphate	0.03	3.18	0.89	0.23
DO	3.84	8.54	5.71	2.42
BOD	2.06	137.15	49.13	8.45
COD	3.48	481.97	104.76	42.18
TDS	105.81	1294.56	540.12	114.63
TSS	36.42	1947.41	619.71	127.15

Phosphate levels were lowest in January, at 0.03 mg L^{-1} in stations 5 and 6. The cold weather and the region's mountainous terrain contributed to a decrease in phosphate concentration. The month of February had the lowest amount of nitrate, equal to 0.07 mg L^{-1}. In September, the lowest DO level measured at stations 9 and 10 (3.84 mg L^{-1}). The BOD of human sewage in the vicinity of the sand and sand workshops, and waste materials from fish breeding ponds (mostly organic substances) into the river, are among the primary causes of the drop in dissolved oxygen in the abovementioned stations. Analyzing the statistical characteristics of water quality variables in different months revealed that in September, the BOD level at station 3 was the lowest (2.06 mg L^{-1}), indicating that the river water was clean. In December, the lowest COD concentration was 3.48 mg L^{-1} at stations 5 and 6. In the mountainous region, the high intensity of the river water flow and the cold weather led to the elimination of pollution. In addition, the lower population density (as a result of the mountainous terrain and cold climate) has led to a reduction in sewage production. The lowest amount of TDS in June was 105.81 mg L^{-1}, measured at stations 2 and 3 in the upstream areas of fish breeding centers which may be due to the high rate of precipitation and the reduction of pollution in the aforementioned stations (Malik *et al.* 2020). The highest concentration of nitrate in June was 7.43 mg L^{-1}, measured at Station 8, since several fish breeding centers are located in this area. The highest phosphate level was measured in August at Station 8 (3.18 mg L^{-1}), due to the placement of several fish breeding ponds in this station and the increase of salts and nutrients inside the ponds. BOD and COD levels were highest in August at Station 9, with 137.15 and 481.97 mg L^{-1}, respectively. Elevating BOD and COD values may be due to the grouping several fish farms and rising the speed of reactions due to the high air temperature. The highest amount of TSS (1947.41 mg L^{-1}) was reported in August at Station 10. High salts, proximity to sand workshops, and increased sand activity this month may be reasons for this elevation (Chow *et al.* 2019).

Statistical analysis

For the obtained data, all parameters were analyzed in 10 sampling stations based on a completely randomized block design, and SPSS 23 software was used to ANOVA. There was a statistically significant difference between sampling stations and periods, as indicated by the analysis of variance results for parameters measured at different stations and during different time intervals. To ensure the correct evaluation of the changes in the parameters measured at the stations, Duncan's test was conducted at a significance level of 5%. The results of ANOVA test are presented in Table 2.

Table 2. ANOVA test and comparison of parameters value in different months.

Parameter		SS*	DF*	MS*	F-value	p-value
Nitrate	Between Groups	142.78	11	12.98	53.19	<0.001
	Within Groups	594.31	54	11.01	-	-
	Total	737.09	65	-	-	-
Phosphate	Between Groups	72.19	11	6.56	83.47	<0.001
	Within Groups	88.04	54	1.63	-	-
	Total	160.23	65	-	-	-
DO	Between Groups	139.43	11	12.68	14.08	0.01
	Within Groups	97.01	54	1.80	-	-
	Total	236.44	65	-	-	-
BOD	Between Groups	128607.56	11	11691.60	4.51	0.03
	Within Groups	94822.83	54	1755.98	-	-
	Total	223430.39	65	-	-	-
COD	Between Groups	2018646.12	11	183513.28	12.73	0.01
	Within Groups	1820394.79	54	33711.01	-	-
	Total	3839040.91	65	-	-	-
TDS	Between Groups	3125465.09	11	284133.19	1.67	0.34
	Within Groups	19037486.71	54	352546.05	-	-
	Total	22162951.8	65	-	-	-
TSS	Between Groups	6526745.34	11	593340.49	24.68	<0.001
	Within Groups	46514597.26	54	861381.43	-	-
	Total	53041342.60	65	-	-	-

*SS= Sum of squares, DF= Degrees of freedom, MS= Mean of squares.

According to the ANOVA test's significant values, there was no statistically significant difference in the amount of TDS ($p < 0.05$). The remaining parameters sampled in different months exhibited significant differences ($p > 0.05$). Consequently, using Duncan's post hoc test to compare TDS parameter values across different months was unnecessary. A significant difference ($p > 0.05$) was reported for the remaining parameters sampled in other months, and two-way comparisons of the sampled parameters were conducted using Duncan's post hoc test. The results of Duncan's post hoc test are presented in Table 3. According to Duncan's test in Table 3, there was a 95% confidence level in the significant difference for nitrate parameter in different months. February, April, July, and March exhibited the lowest nitrate levels caused by the effluent from fish breeding ponds. The highest amount of nitrates was recorded in June, caused by fish breeding ponds' food and waste consumption (Belliard *et al.* 2020). The results of Duncan's test for comparing the phosphate parameter indicated a 95% confidence level in the significance difference between the concentrations in different months. September and August exhibited the highest phosphate levels due to the increase in food consumption and metabolism in fish breeding ponds during the year's warmest months. Due to cold weather, February, April, July, and March recorded the lowest phosphate levels. Fish food and pond production were more significant during the warmer months of the year; consequently, the concentration of DO was lower in August and September which may be due to an elevation in the consumption of dissolved oxygen in fish breeding ponds, which is caused by an upraise in production and metabolism during these months (Holmes *et al.* 2021). BOD alterations were enormous during the hot months of the year, peaking in September which may be due to an elevation in the fish breeding pond production, an upraise in food consumption to feed the fish, an enhance in pond output, including fish waste, and an increase in pond pollution (Koralay & Ömer 2018). Warm weather has also contributed to an elevation in BOD during these times, since warming the air promotes the increased metabolism and, as a result, elevated biological oxygen consumption. The difference between COD amounts in different months of the year was also statistically significant at the 95% confidence level. August was the month that yielded the most significant quantity of COD. The high value of this parameter during this month can be attributed to the heat and increase in oxygen caused by the use of chemicals in fish ponds and industrial areas (Hamilton *et al.* 2022). In October, November, December, and June, COD was lower due to the cold and the decreased consumption of chemicals. Using Duncan's method to compare data, it was determined that the amount of TSS in different months of the year differs significantly at a 95% confidence level. Fish breeding and sandy facilities produced the most total suspended solids (TSS) in August. In September, April, March, February, and November, total suspended solids (TSS) were lower due to the cold and the decline in pollution.

Table 3. Duncan's post hoc test to compare parameters in different stations.

Parameter		SS*	DF*	MS*	F-value	P-value
Nitrate	**Between Groups**	**571.38**	**9**	**63.49**	**67.12**	**<0.001**
	Within Groups	**236.76**	**66**	**3.59**	**-**	**-**
	Total	**808.14**	**75**	**-**	**-**	**-**
Phosphate	Between Groups	58.62	9	6.51	96.53	<0.001
	Within Groups	113.65	66	1.72	-	-
	Total	172.27	75	-	-	-
DO	Between Groups	71.52	9	7.95	23.08	<0.001
	Within Groups	154.19	66	2.34	-	-
	Total	225.71	75	-	-	-
BOD	Between Groups	53267.41	9	5918.60	6.81	0.02
	Within Groups	196439.08	66	2976.35	-	-
	Total	249706.49	75	-	-	-
COD	Between Groups	584132.35	9	64903.59	17.48	0.007
	Within Groups	3436289.13	66	52064.99	-	-
	Total	4020421.48	75	-	-	-
TSS	Between Groups	33648214.06	9	3738690.45	32.92	<0.001
	Within Groups	14285604.83	66	216448.56	-	-
	Total	47933818.89	75	-	-	-

*SS= Sum of squares, DF= Degrees of freedom, MS= Mean of squares.

CONCLUSION

As one of the most critical water resources available to humanity, the problem of river pollution has always been one of the most important topics of research and study in inventing and applying methods to identify and control pollution. In order to apply effective techniques and methods, as well as proper management, to combat these problems, it is necessary and inevitable to understand the reality of the problem and to use models and paths that are as close to and consistent with this reality as possible. Examining the trend of physicochemical parameter alterations in the studied stations revealed that the number of fish breeding ponds has exceeded the permissible limit. Reports indicate that the concentration of pollutants in certain stations is exceptionally high. This is due to the proximity of multiple fish farms. In addition, the concentration of DO in the aforementioned stations has decreased significantly due to an elevation in water oxygen consumption attributable to an upraise in the number of fish breeding ponds in these stations. In general, the study suggested that fish breeding ponds significantly impact the quality of surface water resources. This demonstrates the importance of implementing environmental guidelines and regulations to control the pollution caused by this industry. Special consideration should be given to implementing appropriate management measures to prevent the introduction of pollutants into receiving water resources. In this regard, it is necessary for organizations or institutions issuing licenses to establish fish breeding ponds to consider their environmental impacts prior to issuing the licenses along with conditioning the issuance of licenses on compliance with all applicable environmental regulations and finally, preventing the occurrence of environmental issues in the future through the implementation of correct and principled aquaculture.

REFERENCES

Belliard, J, Beslagic, S, & Tales, E 2020, Changes in fish communities of the Seine Basin over a long-term perspective. The Seine River basin. Handbook of environmental chemistry. Springer, Cham. https://doi.org/10.1007/698_2019_380.

Burke, M, Grant, J, Filgueira, R, & Stone, T 2021, Oceanographic processes control dissolved oxygen variability at a commercial Atlantic salmon farm: application of a real-time sensor network. *Aquaculture,* 533, 736143.

Chow, MI, Lundin, JI, Mitchell, CJ, Davis, JW, Young, G, Scholz, NL, & McIntyre, JK 2019, An urban stormwater runoff mortality syndrome in juvenile coho salmon. *Aquatic Toxicology,* 214, 105231.

Compton, JE, Andersen, CP, Phillips, DL, Brooks, J R, Johnson, MG, Church, MR, McComb, BC 2006, Ecological and water quality consequences of nutrient addition for salmon restoration in the Pacific Northwest. *Frontiers in Ecology and the Environment,* 41: 18-26.

Davidson, J, Redman, N, Crouse, C, & Vinci, B 2022, Water quality, waste production, and off-flavor characterization in a depuration system stocked with market-size Atlantic salmon Salmo salar. *Journal of the World Aquaculture Society*, https://doi.org/10.1111/jwas.12920.

Encina-Montoya, F, Boyero, L, Tonin, AM, Aguayo, MF, Esse, C, Vega, R & Nimptsch, J 2020, Relationship between salt use in fish farms and drift of macroinvertebrates in a freshwater stream. *Aquaculture Environment Interactions,* 12: 205-213.

Farabi, S M V, Golaghaei, M, Sharifian, M & Karimian, E 2022, Effects of rainbow trout farming on water quality around the sea farms in the south of the Caspian Sea. *Caspian Journal of Environmental Sciences,* 20: 729-737.

Gholami, V, Mohseni Saravi, M & Ahmadi, H 2010, Effects of impervious surfaces and urban development on runoff generation and flood hazard in the Hajighoshan watershed. *Caspian Journal of Environmental Sciences,* 8: 1-12.

Hamilton, S, Murphy, C, Johnson, S & Pollock, A 2022, Water quality ramifications of temporary drawdown of Oregon reservoirs to facilitate juvenile Chinook salmon passage. *Lake and Reservoir Management,* 38: 165-179.

Hause, CL, Singer, GP, Buchanan, RA, Cocherell, DE, Fangue, NA, & Rypel, AL 2022, Survival of a threatened salmon is linked to spatial variability in river conditions. *Canadian Journal of Fisheries and Aquatic Sciences*.

Holmes, EJ, Saffarinia, P, Rypel, AL, Bell-Tilcock, MN, Katz, JV, & Jeffres, CA 2021, Reconciling fish and farms: Methods for managing California rice fields as salmon habitat. *PlosOne,* 16: e0237686

Hukom, V, Nielsen, R, Asmild, M, & Nielsen, M 2020, Do aquaculture farmers have an incentive to maintain good water quality? The case of small-scale shrimp farming in Indonesia. *Ecological Economics*, 176: 106717

Kochalski, S, Riepe, C, Fujitani, M, Aas, Ø & Arlinghaus, R 2019, Public perception of river fish biodiversity in four European countries *Conservation Biology,* 33: 164-175

Koed, A, Birnie-Gauvin, K, Sivebæk, F, & Aarestrup, K 2020, From endangered to sustainable: Multi-faceted management in rivers and coasts improves Atlantic salmon *Salmo salar* populations in Denmark. *Fisheries Management and Ecology,* 27: 64-76

Koralay, N, & Ömer, K 2018, Forestry activities and surface water quality in a rainfall watershed. *European Journal of Forest Engineering,* 4: 70-82

Kristensen, T, Åtland, Å, Rosten, T, Urke, H, & Rosseland, B 2009, Important influent-water quality parameters at freshwater production sites in two salmon producing countries. *Aquacultural Engineering,* 41: 53-59

Kroglund, F, Rosseland, B, Teien, H-C, Salbu, B, Kristensen, T, & Finstad, B 2008 Water quality limits for Atlantic salmon Salmo salar L exposed to short term reductions in pH and increased aluminum simulating episodes. *Hydrology and Earth System Sciences,* 122: 491-507

Maest, A, Prucha, R, & Wobus, C 2020 Hydrologic and water quality modeling of the pebble mine project pit lake and downstream environment after mine closure. *Minerals,* 10: 727

Malik, D, Sharma, AK, Sharma, AK, Thakur, R, & Sharma, M 2020, A review on impact of water pollution on freshwater fish species and their aquatic environment. *Advances in Environmental Pollution Management: Wastewater Impacts and Treatment Technologies,* 1: 10-28

Meshesha, T W, Wang, J, & Melaku, N D 2020, Modelling spatiotemporal patterns of water quality and its impacts on aquatic ecosystem in the cold climate region of Alberta, Canada. *Journal of Hydrology,* 587: 124952

Quiñones, RA, Fuentes, M, Montes, RM, Soto, D, & León-Muñoz, J 2019, Environmental issues in Chilean salmon farming: a review *Reviews in Aquaculture,* 11: 375-402

Rahbar, M, Nezami, S, Khara, H, Rezvani, M, & Eslami, S 2011, Effect of age on reproductive performance in female Caspian brown trout Salmo trutta caspious, Kessler 1877. *Caspian Journal of Environmental Sciences,* 9: 97-103

Saltveit, SJ, Brabrand, Å, & Brittain, JE 2019 Rivers need floods: Management lessons learnt from the regulation of the Norwegian salmon river, Suldalslågen. *River Research and Applications,* 35: 1181-1191

Thorstad, EB, Bliss, D, Breau, C, Damon-Randall, K, Sundt-Hansen, LE, Hatfield, EM & Sheehan, T 2021, Atlantic salmon in a rapidly changing environment-Facing the challenges of reduced marine survival and climate change. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 31: 2654-2665

Varol, M 2019 Impacts of cage fish farms in a large reservoir on water and sediment chemistry *Environmental Pollution,* 252: 1448-1454

Yilmaz, E, & Koç, C 2014 Physically and chemically evaluation for the water quality criteria in a farm on Akcay. *Journal of Water Resource and Protection,* 6 (2), DOI: 10.4236/jwarp.2014.62010.

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