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A study on the impact of physicochemical and hydrographic factors of water on the nutrients pollution in the sediments in the Karun River

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Abstract
Background: Water pollution from nutrients is a major environmental challenge. This study investigated the relationship between physicochemical and hydrographic components with nitrates and phosphates in the Karun River, Ahvaz.
Methods: Forty samples were obtained from 10 different areas from the northern regions of the river to the south of Ahvaz city in all four seasons of 2023, using the Peterson grab for sediments and a 1-liter glass for water. The Hach Spectrophotometer (model DR2800, the United States) was used to measure nitrate and phosphate levels. River discharge was measured using the Guage method, evaporation rate was determined using the transpiration method, sedimentation rate was calculated using bathymetric maps, average friction was determined using the Chézy method, particle diffusion coefficient was calculated using the transverse method, and mass remaining rate was based on Yang's wave movement equations.
Results: The results showed that water quality characteristics such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), turbidity, and total suspended solids (TSS) in the samples from the northern areas were significantly better than in samples from the lower areas. Nitrate levels ranged from 21.81 to 23.95 mg/L, and phosphate levels ranged from 3.37 to 6.76 mg/L. There was a significant correlation between river discharge, evaporation rate, sedimentation rate, mass remaining, particle diffusion coefficient, and phosphate levels ($P < 0.05$). However, no significant relationship was found between these parameters and nitrate levels.
Conclusion: The findings are essential for understanding the relationship between hydrographic parameters and nutrient levels in water sources, which can lead to more effective environmental management strategies.
Keywords: Water quality, Rivers, Nitrate, Phosphates, Karun River
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Introduction

Rivers play a vital role in the Earth's life cycle as essential arteries. The importance of water is predicted to increase significantly in the future to become the main focus of discussions and the driving force of development for countries in the world (1,2). Various factors, such as industrial, service-related, agricultural, and natural, contribute to the pollution of surface water sources. Among the factors contributing to pollution, wastewater and chemical fertilizers containing pollutants such as phosphates and nitrates are significant (3,4). Nitrates are ions resulting from a part of the nitrogen cycle, formed by aerobic bacteria breaking down ammonia molecules into nitrites and nitrites into nitrates (5,6). Under ideal conditions, nitrates can break down into their constituent elements, free nitrogen, and stripped oxygen, completing the nitrogen cycle (7). Nitrates transform into a food source for the growth of unwanted algae in water sources (8). Inorganic phosphates consist of ions made from a combination of phosphorus, oxygen, and hydrogen found in all parts of living organisms, serving as the primary source of phosphate release into water (9). Phosphates act as inhibitors of calcium absorption and skeleton formation in corals, sponges, and certain algae (10). High levels of phosphates are considered a threat to water resources. Excessive levels of these pollutants lead to the excessive growth and stimulation of aquatic animals and algae (11). The excessive growth of various organisms leads to clotting and accumulation, blocking marine pathways and consuming all the dissolved oxygen (DO) in the water (12). Phosphate pollution also results in increased sludge and suspended solids (13). An increase in nitrates and phosphates can lead to increased toxicity and disruption in aquatic ecosystem systems. An increase in nutrients can lead to the growth of aquatic plants, which can destroy aquatic ecosystems and lead to the extinction of other animal species (14). Amounts exceeding 0.1 mg/l of phosphates and 10 mg/l of nitrates pose serious risks to the ecosystem (15). New research findings indicate that human activities globally annually release 2.2 million tons of phosphorus into the major freshwater basins of the world (16). Agricultural and industrial activities are the main contributors to these two types of pollution in water sources (17). Examining the levels of nutrients in water sources is also important in environmental management. Several studies have demonstrated a significant correlation between numerous physicochemical, hydrological, and sedimentary components of water and the levels of nutrients. The study by Renner et al (18) showed that hydrograph diversity has led to significant changes in nutrient concentrations in the inflow from the Atlantic Ocean to the Arctic Ocean. Delgadillo-Hinojosa et al (19) also demonstrated that temperature changes affect the levels of nutrients in water on the northern coast of California in the 2014-2015 period. Becker et al (20) stated that changes in the levels of soluble substances in water have led to changes in nutrient levels. Determining the current nutrient rates and the influencing factors in water resource management is effective for health and environmental sustainability. The Karun River is the wettest, largest, and longest river in Iran, with a length of 950 kilometers passing through 10 cities. Besides being a habitat for many plant and animal species, it is responsible for providing drinking, agricultural, and industrial water in southwest Iran (21). Numerous reports of water pollution in this river have been published in recent years (22-24).

In this research, in addition to studying the water pollution of the Karun River with nutrients, the effect of hydraulic factors such as flow velocity, bed depth, particle size of bed sediments, evaporation rate, mass rate, and diffusion on changes in the rate of nutrients (phosphate and nitrate) in sediments. The Karun River has been investigated.

In the present study, the pollution status of the river to nutrients (nitrates and phosphates), the physicochemical characteristics of the water within the Khuzestan province, and its hydrological components were examined, investigating the relationship between these components. The results of this study will play an effective role in the environmental management of this river. This study not only assessed the concentrations of nitrates and phosphates in sediments but also analyzed how various hydrological parameters, such as river discharge, evaporation rates, sedimentation rates, and particle diffusion coefficients, affect nutrient levels. This multifaceted approach allows for a more nuanced understanding of the interactions between physical processes and nutrient pollution, which has been largely overlooked in prior studies.

Study area

Karun is the longest river in Iran. Its catchment area is 65 230 km^2. Eleven dams and power plants on the Karun River are in the stage of operation, construction, or research, and their total volume will be 21 billion and 559 million cubic meters when completed. The average daily, monthly, and ecological water flow of the Karun River is 536, 631, and 290 cubic meters per second, respectively.

During high water periods (March to June), the average water flow of the Karun River reaches about 1000 to 1500 cubic meters per second (m^3/s). The average depth of the river increases to about 6 to 10 meters during this period. These statistics show the importance of this river in providing water resources in the southwest of Iran. Field surveys and studies show that the water quality index (WQI) of this river, from a distance of 140 km north of Ahvaz city, decreases over time, which is due to the entry of large amounts of industrial and agricultural effluents (25).

About 40% of the total bed sediments are sand and pebbles with a size of 0.06 to 20 mm. The location of the Karun River and the sampling points are presented in Figure 1.

Materials and Methods

The present descriptive-applied research was conducted to investigate the relationship between the physicochemical and hydrographic components of the Karun River and nutrients (nitrate and phosphate) in the sediment bed in 2023. Sampling was done in January, April, July, and October of 2023 (40 samples in total). Water samples were collected in 1-liter glass containers, and sediment samples were collected in 500-gram containers. Sampling of the sediments was done using a Peterson grab. The selection of 10 different areas along the Karun River allowed us to better examine geographic variation and local impacts on water quality and nutrient pollution. This diversity can be caused by environmental, human, and natural differences that affect water quality. The strategy of determining the sampling points was based on the north and south distances from the city, so that the samples were from 80 km from the north to 40 km after this city.

Nitrate and phosphate measurement method

A Hach dr2800 spectrophotometer was used to determine the amount of phosphate and nitrate in water samples. In this method, we filtered and diluted the sample. The limit of

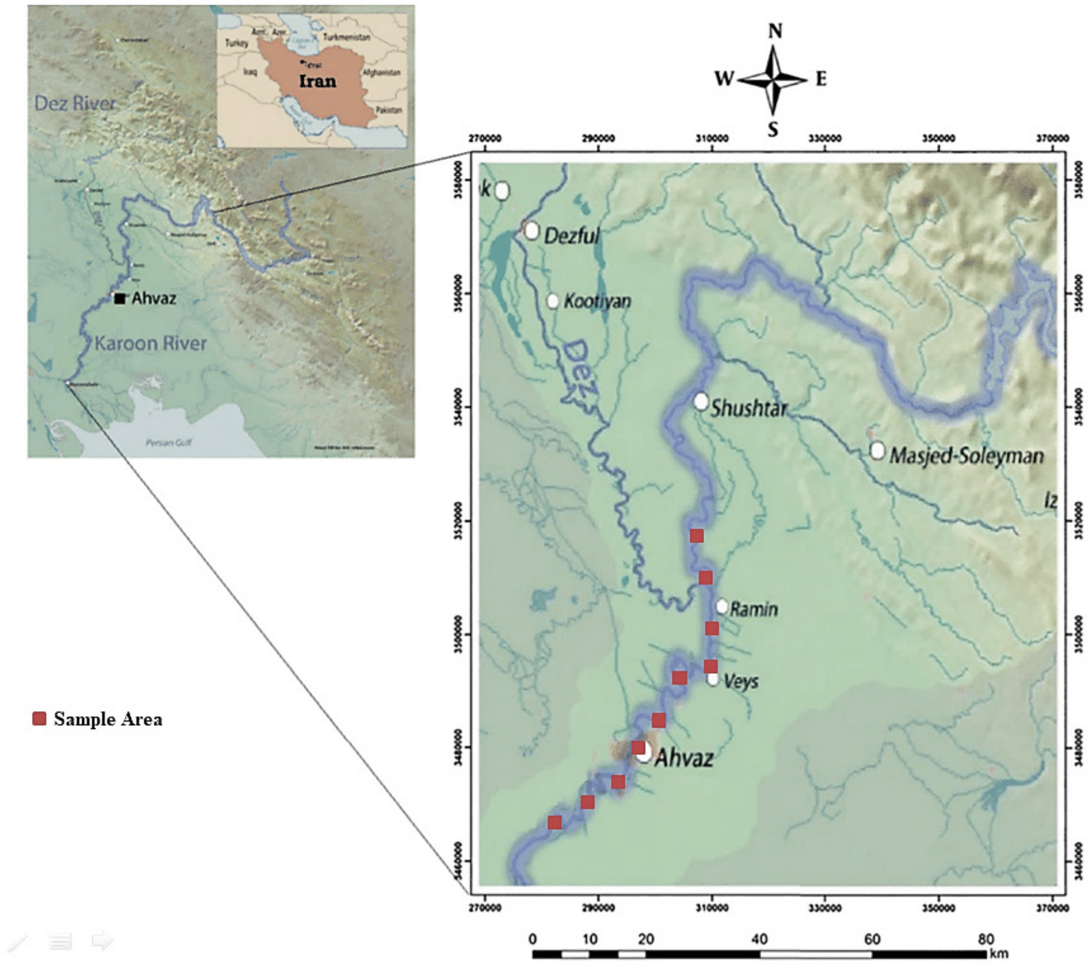

Figure 1. Geographical location of the Karun River and sampling points

detection for nitrate and phosphate was 0.1 and 0.01 mg/L, respectively. Then, 10 cc of the sample was poured into the corresponding cells, and the settings of the device were set to measure the concentration of phosphate (PO_4). To measure the nitrate by this method, ultraviolet absorption at a wavelength of 220 nm was measured. Considering that organic substances also absorb this wavelength, it is necessary to eliminate the interference of organic substances. The second measurement was done at 275 nm to correct the amount of nitrate. Phosphate concentration was also measured at a wavelength of 720 nm.

Determining the grading of sediments

Soil grading was determined based on the ASTM C136 standard and based on the sieve analysis method. In this method, the sample is successively passed through a series of sieves of different sizes. Grains are registered according to their size in each sieve, and the ratio of the weight of the sample to the weight of the set of prominent grains in each size is calculated (26,27).

Determining the river discharge

Due to the existence of numerous waterways connected to the Karun River, the water flow is different in different places. The measurement has been done through the reading Gauge. In this method, a curve is created, which is the result of direct measurements of Debye and Eschel (28).

Calculating the evaporation rate

To calculate the evaporation rate in the Karun River, the seepage evaporation method was used. In this method, changes in air temperature, relative air humidity, wind speed, and solar radiation on the water surface are considered. These parameters directly affect the evaporation of water from the river surface. To perform the calculations, the Penman-Monteith evaporation equation (1) was used:

$$E = \frac{(0.408 * \Delta * (Rn - G) + \gamma * (900 / (T + 273)) * u2 * (es - ea)}{(\Delta + \gamma * (1 + 0.34 * u2)} \quad \text{Eq. (1)}$$

Where E is the evaporation rate (mm/day), Δ is relative precooling, Rn is gross solar radiation ($MJ/m^2/d$), G is solar heating to the Earth's surface ($MJ/m^2/d$), γ = Total water vapor, T is ambient air temperature (degrees Celsius), $u2$ is wind speed at altitude (m/s), H is the vapor pressure of saturated water vapor (kPa), and ea is the vapor pressure of ambient water vapor (kPa) (29).

Calculating the sedimentation rate

The rate of sedimentation was determined using the data from drawing a bathymetric map of the Karun Riverbed and drawing longitudinal and transverse profiles at the sampling points in a one-year interval.

Average friction factor

The Chézy method was used to determine the rate of the friction factor of the riverbed. This method uses Chézy's law, based on which, the rate of the bed friction factor component is calculated using Eq. 2:

$$v = C\sqrt{(rS)} \qquad \text{Eq. (2)}$$

In this regard, *v* is the rate of the bed friction factor, *C* is the Chézy coefficient, which is a constant, *r* is the radius of the river flow, and *S* is the curvature of the riverbed (30).

Diffusion coefficient of substrate particles

The standard method of the terrace test was used to determine the distribution coefficient of bed particles in the Karun River. In this method, test equipment, including a drop source from a pillow washer, a test tube with a specified diameter, and a metro-chronometer cup, was used. First, a mixture of riverbed particles and water is placed in the test tube, and then, with a source of pressure drop, water and particles pass through the tube. Then, using a metro-chronometer cup, the particles that came out of the tube due to the pressure drop were measured. Due to its high accuracy and repeatability, this method is one of the methods used in determining the spreading coefficient of bed particles in rivers (31).

Equations of motion in the Karun Riverbed particles

Considering that in previous studies, it has been shown that a large part of nutrients is deposited in the bed of rivers and is related to the silicates of bed sediments (32), the survival rate of particles in the bed can be related to nutrients. However, the level of communication is affected by other environmental and hydraulic factors. In the present research, two-dimensional equations were used to estimate the survival of particles in the averaged flow in the depth of the Karun Riverbed. These equations include the equation of mass conservation and two equations of conservation of wave motion. The system of the mentioned equations is according to equations 3 to 9:

$$\frac{\partial h\rho}{\partial t}+\frac{\partial h\overline{u}}{\partial x}+\frac{\partial h\overline{v}}{\partial y} \qquad \text{Eq. (3)}$$

The conservation equation of the amount of movement in the x direction is as follows:

$$\frac{\partial h\overline{u}}{\partial t}+\frac{\partial h\overline{u2}}{\partial x}+\frac{\partial h\overline{uv}}{\partial y}=f\overline{v}h-gh\frac{\partial n}{\partial x} \qquad \text{Eq. (4)}$$

$$\frac{h}{\rho_0}+\frac{\partial\rho_0}{\partial x}-\frac{gh^2}{2\rho_0}+\frac{\partial\rho}{\partial x}+\frac{t_{sx}}{\rho_0}-\frac{t_{bx}}{\rho_0}-\frac{1}{\rho_0}\left[\frac{\partial s_{xx}}{\partial x}+\frac{\partial s_{xy}}{\partial y}\right] \qquad \text{Eq. (5)}$$

$$\frac{\partial}{\partial x}(\mathrm{hTxx})+\frac{\partial}{\partial y}(\mathrm{hTxy})+\mathrm{husS} \qquad \text{Eq. (6)}$$

The equation of survival of the amount of movement in the y direction is as follows:

$$\frac{\partial h\overline{v}}{\partial t}+\frac{\partial h\overline{v2}}{\partial y}+\frac{\partial h\overline{uv}}{\partial t}+=f\overline{u}h-gh\frac{\partial n}{\partial y}-\frac{h}{\rho_0}=\frac{\partial\rho_0}{\partial y} \qquad \text{Eq. (7)}$$

$$\frac{gh^2}{2\rho_0}+\frac{\partial\rho}{\partial y}+\frac{t_{sy}}{\rho_0}-\frac{t_{by}}{\rho_0}-\frac{1}{\rho_0}\left[\frac{\partial s_{yy}}{\partial y}+\frac{\partial s_{yx}}{\partial x}\right] \qquad \text{Eq. (8)}$$

$$\frac{\partial}{\partial x}(\mathrm{hTxx})+\frac{\partial}{\partial y}(\mathrm{hTxy})+\mathrm{hvsS} \qquad \text{Eq. (9)}$$

Where:
$\eta = d + h$

Where *d* is the average water depth and *h* is the water level (33). After determining the qualitative characteristics, amount of nutrients, and hydrographic components, the statistical methods of Pearson correlation, linear regression, and cluster analysis dendrogram were used to determine the relationship between these variables.

Results

The results of the average water quality components of the Karun River in 10 sampling areas in 4 seasons are presented in Table 1. The quality characteristics of water in area No. 1, which has the greatest distance to Ahvaz city, have a better quality. The average biochemical oxygen demand (BOD) value in sample number one was 5.23 mg/L, and in sample 8 (8.12 mg/L). The results of the water quality analysis of the Karun River at 10 sampling locations are outlined in Table 1, with a comparison of the quality parameter values depicted in Figure 2.

The results of the analysis of phosphate and nitrate levels in water samples collected from the Karun River during 4 sampling periods in 2023 are displayed in Figure 3. Nitrate levels ranged from 21.81 to 23.95 mg/L, falling within the 20-30 range classified as unsuitable quality according to the WQI (34). Phosphate levels ranged from 3.37 to 6.76 mg/L, falling within the 8-10 range classified as very poor quality according to the WQI index for river water.

The dendrogram of cluster analysis illustrating the correlation between the quality parameters of the Karun River in Figure 3 reveals that, aside from DO showing an inverse correlation, other water pollution parameters such as BOD and chemical oxygen demand (COD),

Table 1. The results of measuring the water characteristics of the Karun River in 10 sampling areas in 4 seasons of the year

Sample No.	BOD		COD		Phosphate		Nitrate		DO		Turbidity		TSS		EC	
	ppm		ppm		mg/L		mg/L		ppm		NTU		mg/L		us/cm	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	5.23	0.42	8.14	0.77	3.37	0.21	21.81	2.37	2.18	0.16	16.9	1.04	63.1	5.72	2449.1	15.1
2	5.61	0.89	9.26	0.84	3.79	0.25	21.93	2.53	2.12	0.23	17	1.26	62.7	4.63	2470.3	16.3
3	5.52	0.73	8.83	1.03	4.11	0.27	22.27	2.72	2.11	0.21	16.8	1.07	65.2	4.7	2471.3	17.5
4	7.01	1.01	12.23	1.37	4.23	0.34	22.58	2.17	2.01	0.25	17.2	1.56	63.1	5.86	2483.5	18.3
5	7.27	0.94	12.85	1.72	5.89	0.4	22.83	2.63	1.98	0.27	17.3	1.35	67.2	3.99	2493.7	16.2
6	7.87	0.79	14.52	1.82	6.23	0.52	23.27	2.52	1.84	0.2	18.5	1.54	70.1	4.31	2503.1	14.1
7	8.12	1.08	17.43	3.06	6.76	0.79	23.59	2.73	1.81	0.18	18.7	1.73	72.9	4.27	2513.8	15.6
8	7.65	1.01	15.62	2.52	6.54	0.77	23.5	3.08	1.95	0.23	18.3	1.95	69.3	4.56	2499.4	16.4
9	6.18	0.63	12.37	1.64	5.13	0.53	22.05	2.69	2.1	0.17	17.7	1.37	65.2	4.62	2453.1	14.7
10	5.52	0.54	9.04	1.04	5.29	0.36	22.48	2.6	2.14	0.2	17.1	1.13	62.4	4.78	2468.6	13.3

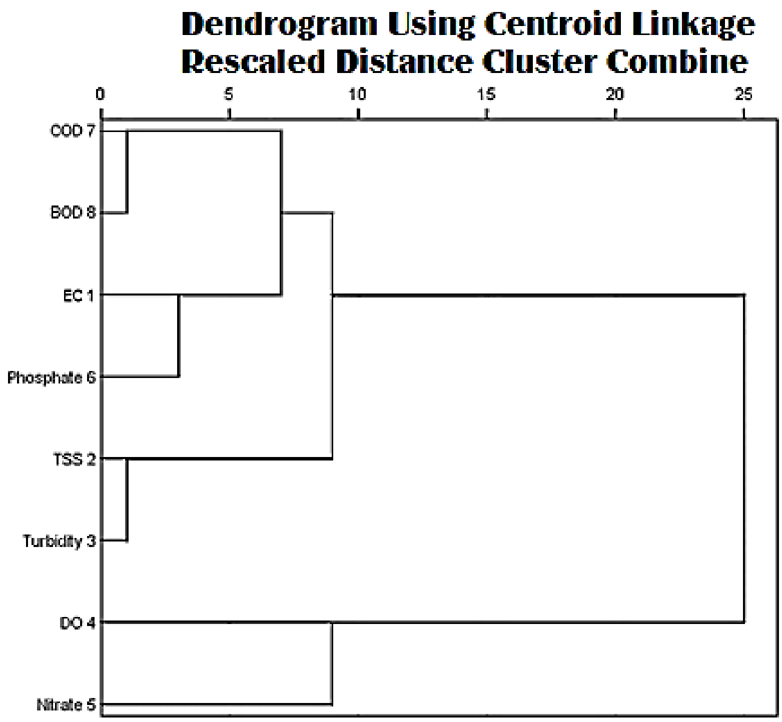

Figure 2. Dendrogram of cluster analysis of the correlation between quality characteristics of Karun River water

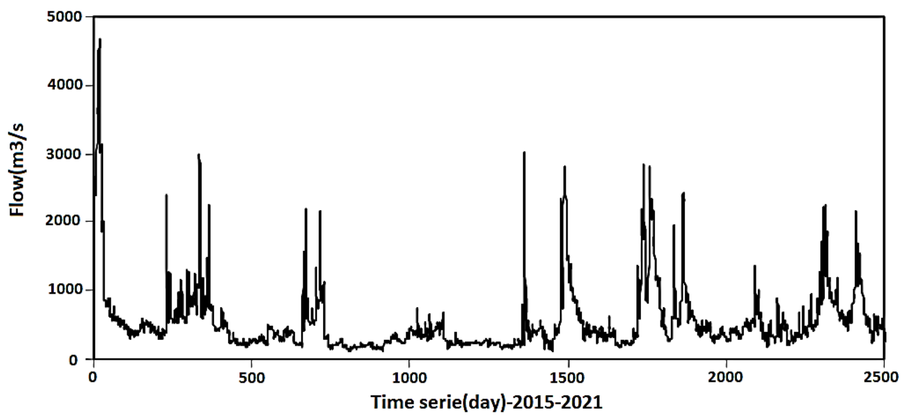

Figure 3. The flow rate of the Karun River over 7 years (2015-2021)

as well as total suspended solids (TSS) and Turbidity, exhibited strong correlations. Additionally, the nitrate and phosphate levels displayed a positive correlation with the increase in other water pollution parameters within the samples.

The analysis of the average flow rate of the Karun River and bed particle dimensions from 2015 to 2021 is depicted in Figure 4.

Figure 5 shows the slight changes in the size of bed sediment particles over 7 years in the Karun River. The research findings indicate that smaller particles within the riverbed are capable of retaining more nutrients and transporting them along with the river's flow.

Water samples were also taken to identify the subsurface layers of the Karun River. The purpose of sampling was to determine the concentration of suspended sediments in water. The laboratory analysis of this sample showed that the average concentration of suspended sediments was 38 mg/L.

The results of the analysis of the hydrographic components of the Karun River in 10 sampling areas are presented in Table 2. These components include

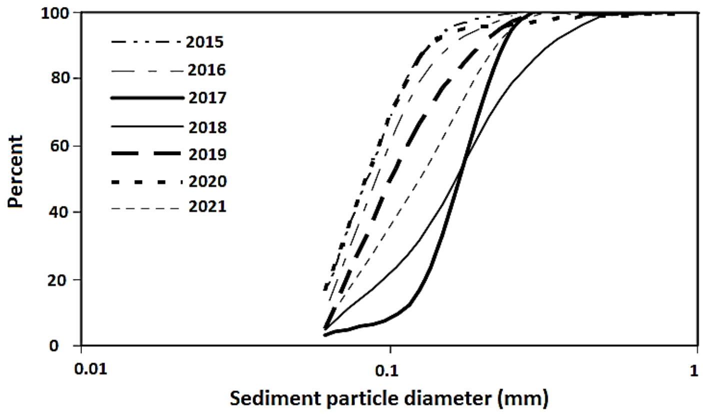

Figure 4. The results of the analysis of the dimensions of the sediment particles of the Karun riverbed over 7 years (2015-2021)

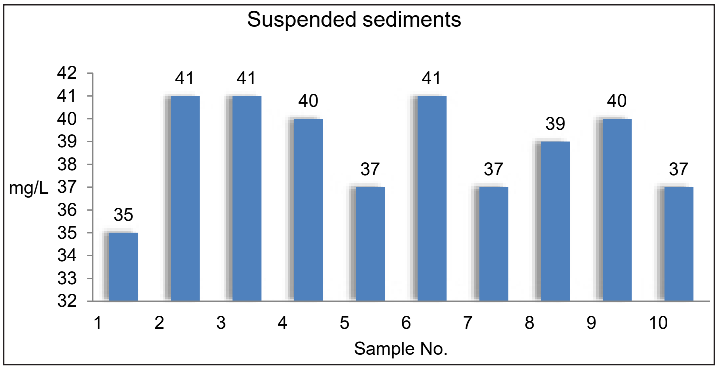

Figure 5. The average concentration of suspended sediments in the Karoon River in 10 sampling areas

Table 2. Results of the average hydrographic components of the Karun River in 10 sampling areas in 4 seasons of 2023

Sample	River discharge (m^3/s)	Annual evaporation rate (mm)	Average bed depth (cm)	Annual sedimentation rate (mm)	Average friction factor	Mass remaining rate (%)	Diffusion coefficient of substrate particles (um^2/s)
1	431	1389	763	24	0.031	0.69	0.8
2	430	1392	985	24	0.03	0.72	0.83
3	375	1391	958	23	0.031	1.04	0.83
4	371	1394	1481	26	0.029	0.95	0.84
5	370	1404	693	27	0.03	1.04	1.64
6	370	1435	780	27	0.032	1.54	2.93
7	352	1457	699	28	0.034	1.23	2.78
8	352	1501	723	28	0.037	1.46	2.86
9	351	1497	771	29	0.039	1.39	3.19
10	351	1496	803	28	0.04	1.19	1.54

river water discharge (m^3/s), annual evaporation rate (mm), average bed depth (cm), annual sedimentation rate (mm), average friction factor, mass remaining rate, and bed particle diffusion coefficient (um^2/s). To analyze the relationship between nutrients and hydrographic parameters, components that have focal values and are variable along the river course, were selected.

The dendrogram of the cluster analysis of the relationship between nitrate and phosphate values with the hydrographic parameters of the Karun River is presented in Figure 6. The results have shown that there is a significant negative correlation between the flow rate of river water and the amount of phosphate ($P<0.05$). With the increase in flow rate, the amount of phosphate decreased. High discharge means more irrigation, and in such conditions, the ratio of polluting compounds to water decreases. In high discharge, the speed of water flow increases, and as a result of this fast flow, pollutants are transported from the riverbed. The regression relationship diagram of nitrate and phosphate values and the hydrographic parameters of the Karun River are presented in Figures 7 and 8.

The correlation between the mass remaining and phosphate rates has also been positive and significant. The mass remaining rate is considered as the amount of mass of living details in the environment, and this amount is usually dependent on environmental factors such as nutrition, temperature, oxygen, pH, and organic matter. On the other hand, phosphate is one of the important constituents of river sediments, which indirectly affects the viability of organisms.

Discussion

Rivers function as complex systems regarding hydraulics and the environment, engaging in various ecological and chemical processes within them. One of the most important aspects of river functioning is the relationship between hydraulic components of water (including discharge, flow velocity, and flow pattern) and the concentrations of nutrients, particularly nitrates and phosphates, in the bed sediments.

The pollution of riverbeds with nutrients such as nitrates and phosphates is a serious environmental issue that can have negative impacts on water quality and aquatic ecosystems. The Karun River, as the largest river in Iran, is influenced by agricultural and industrial activities as well as urban wastewater, which leads to an increase in the concentration of these nutrients in its water and sediments. The results of the present research have shown a significant level of contamination of bed sediments with nutrients. The ideal values of BOD for river water are less than 3 ppm (35). The average values of BOD in the samples of the current research in the Karun River are more than the previous measurements (36). The lowest standard deviation of measured BOD values between sampling seasons was in the first sample. In proportion to BOD, COD values have also increased. As anticipated, in cases where BOD and COD values showed an increase, the DO value demonstrated a decrease. Station number 8, located immediately outside Ahvaz City, was identified as the most contaminated sampling site. These findings underscore the significant impact of urban pollutants on the pollution levels of the Karun River. Turbidity levels

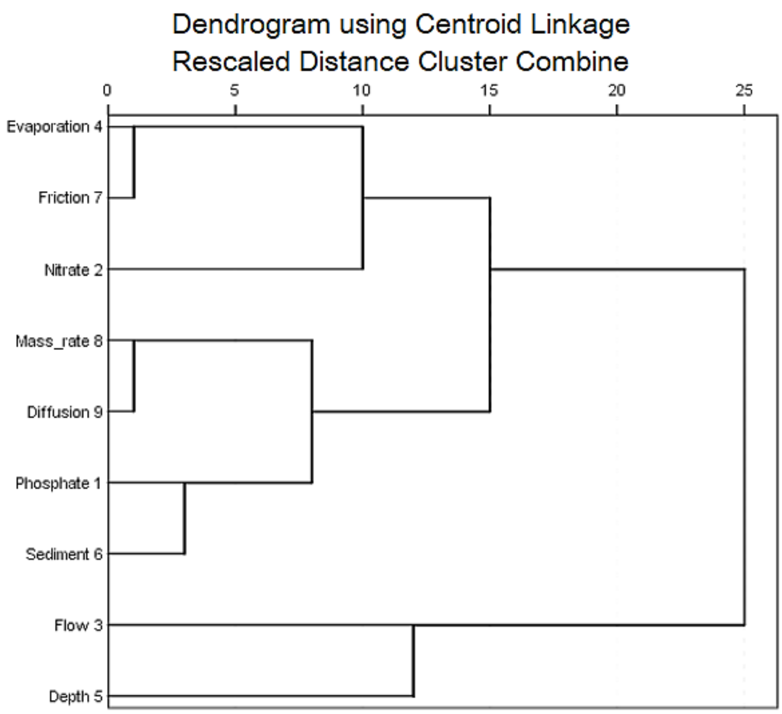

Figure 6. Dendrogram of cluster analysis of the relationship between nitrate and phosphate values with the hydrographic parameters of Karon River water

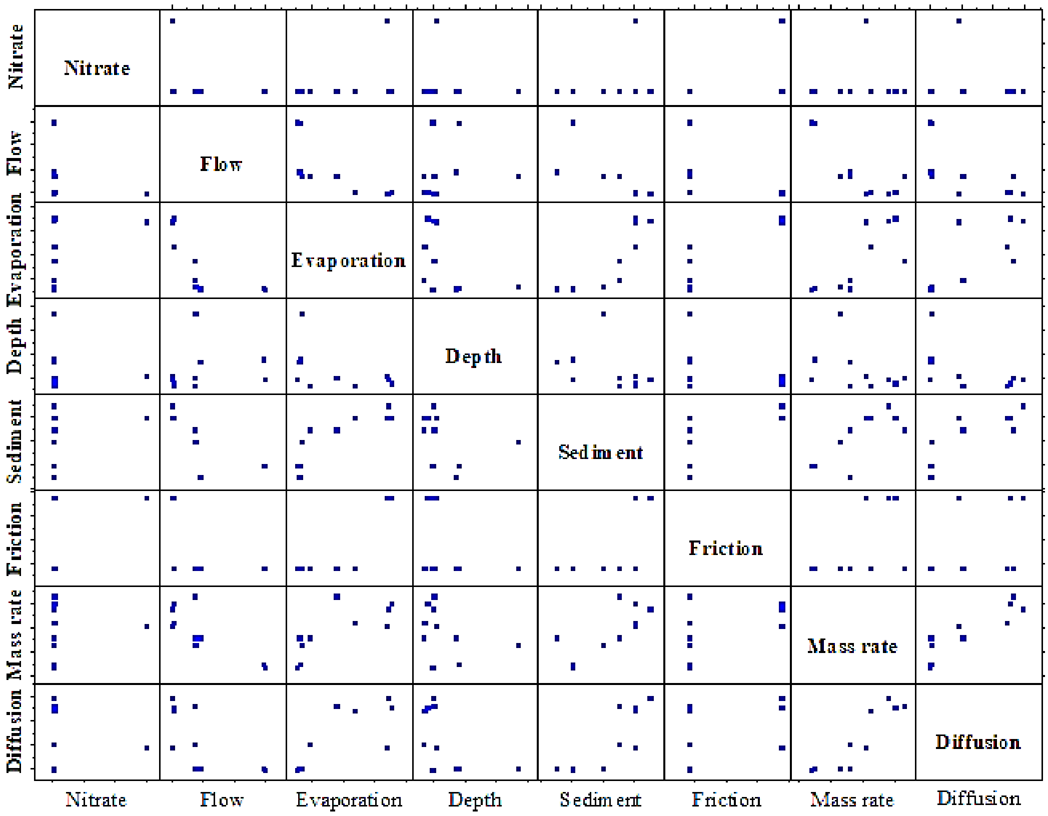

Figure 7. Regression diagram of nitrate values and hydrographic parameters of Karun River water

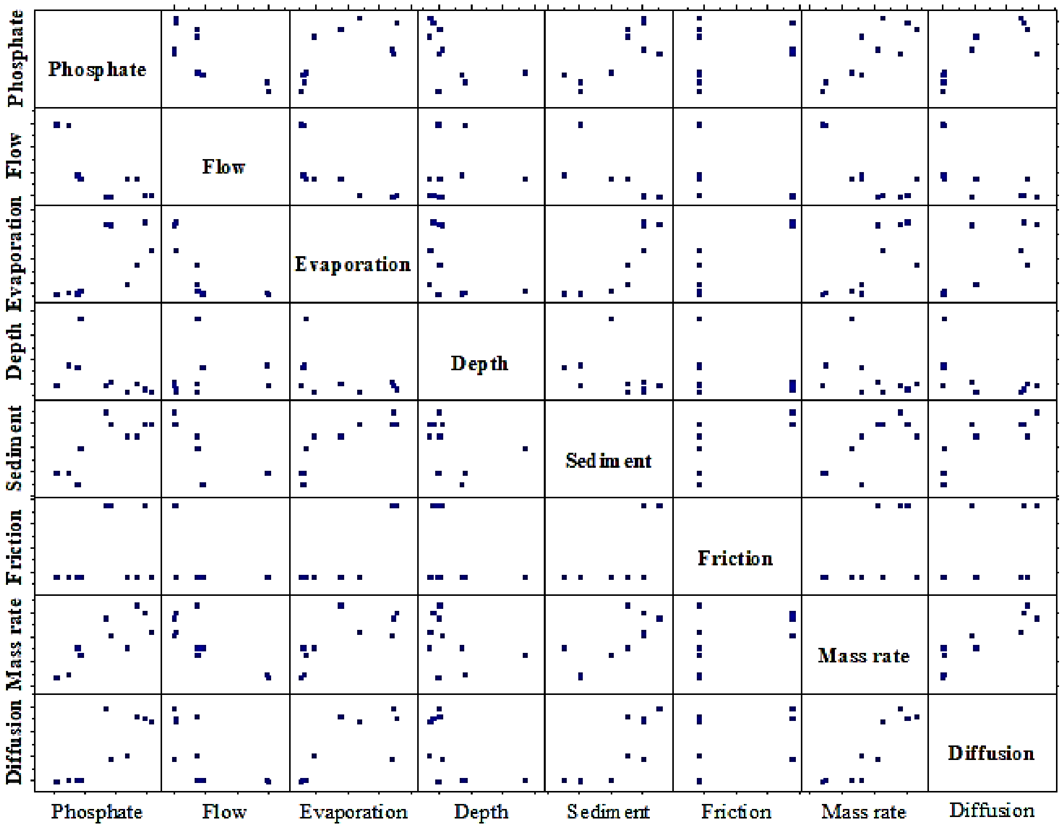

Figure 8. Regression diagram of phosphate values and hydrographic parameters of Karon River water

fluctuated between 16.9 and 18.7 NTU, exceeding the accepted turbidity threshold of 10 NTU for river water (37). TSS and EC values exhibited a comparable upward trend from samples 1 to 8.

Based on the results, the pollution levels of nitrate and phosphate in the samples collected were high. The seasonal variations (standard deviation statistics) in nitrate and phosphate levels for samples 4, 5, 6, 7, 8, and 9 were considerable, indicating the influence of environmental factors on pollution levels.

While industrial and agricultural waste are the main contributors to nitrate and phosphate pollution in the Karun River (38), various geographical, hydrographic, and climatic factors can also impact the levels of nutrient pollution in the water. Ganji et al (39) reported that climate change has had an impact on the water quality in the Karun River, with projections indicating a rise in pollution levels due to agricultural and industrial growth until 2050. Zingde et al (40) showed that changes in sedimentation rate and average bed depth between 1976 and 1978 led to an 11.7% increase in water pollution load at Mumbai port. Larger particles can mechanically trap additional suspended matter and nutrients, thus limiting their movement (41). Another study revealed that particles smaller than 0.063 mm tend to retain higher levels of nitrate and phosphate, preventing their displacement. Essentially, finer particles present in the riverbed contribute to enhancing water quality (42).

The findings show that the bed sediments in Ahvaz city are predominantly sandy, transitioning to finer particles in the northern region. Beyond the city limits, towards the river's southern stretch, a single sediment sample primarily consists of very fine silt and clay particles. Generally, across the depicted locations, the particles comprise a mix of sand, clay, and silt.

Considering the limitation of sampling in the present research, conducting similar research in long-term periods can provide more accurate results on the relationship between hydrographic components and nutrients, and other water quality parameters. The average bed depth also had an inverse correlation with nutrients, but this correlation was not statistically significant. The sedimentation rate also has a significant positive correlation with the increase of inorganic phosphate. Areas of high sedimentation rates usually include areas with high human activity, such as agriculture, urban, industrial, etc. These activities can lead to the introduction of large amounts of phosphates into water resources. High sedimentation can lead to the accumulation of phosphate and nitrate in water sources because these substances may be permanently placed in water and not decomposed by biological and chemical activities in water. The mass remaining rate affects the physicochemical properties of river water (43). There have been similar results for heavy metals (44) and microplastics (45). A significant correlation has been observed between the rate of evaporation and the amount of phosphate. Increasing the rate of evaporation also means a decrease in irrigation and a higher concentration of nutrients (46). On the other hand, with the increase in water temperature, the rate of DO decreases and BOD increases due to the increase in the activity of microorganisms. The results of the present study revealed that the water quality characteristics of the Karun River, particularly the levels of phosphate and nitrate nutrients in the samples from Ahvaz city and downstream, exhibit a high level of contamination compared to samples from upstream. The highest recorded nitrate and phosphate levels in the eighth sample were 23.95 and 6.76 mg/L, respectively. Statistical analysis indicated a significant correlation between water quality parameters and nutrient levels.

The results of the study by Colborne et al (47) showed that nitrate levels in the range of 15 and phosphate levels of 4 mg/L were reported in Laurentian Lake sediments. The significant correlation between water quality parameters and nutrient levels in this study is consistent with the results of the study by Wu et al (48), which showed that increasing nutrient concentrations led to a decrease in water quality in Daihai Lake. This relationship could be due to the destructive effects of nutrients on aquatic ecosystems.

Examination of hydrographic parameters demonstrated that factors such as flow velocity, river discharge, evaporation rate, mass remaining, and diffusion coefficient were closely linked to nutrient levels. Some hydrographic factors and sediment properties were found to be impacted by human activities.

Conclusion

The results of the research show a significant level of nitrate and phosphate contamination of the sediments of the Karun Riverbed. Also, some hydraulic components, such as flow velocity, river discharge, evaporation rate, and residual mass, showed a significant correlation with the level of contamination of bed sediments with nutrients. The findings are essential for understanding the relationship between hydrographic parameters and nutrient levels in water sources, which can lead to more effective environmental management strategies. Understanding the relationship between hydrographic and hydraulic parameters of water with nutrient pollution levels could aid in identifying the sources of pollution and developing effective environmental management strategies.

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Authors' contributions

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Competing interests

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Furthermore, the ethical issues have been completely observed by the authors, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy.

Ethical issues

The Research Ethics Committee of Islamic Azad University of Ahvaz approved this study (Ethical code: 1064817541945751399162355108)

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