University of Tehran Press

Online ISSN: 2345-475X

DESERT

Home page: https://jdesert.ut.ac.ir/

Physicochemical Changes and Possibility of Eutrophication by a Water Transfer to International Parishan Wetland, Iran

Bahareh Samadi Kuchaksaraei[1], Kamran Rezaei Tavabe[1*], Maryam Aghajani[2]

[1] Department of Fisheries, Faculty of Natural resources, University of Tehran, Karaj, Iran.
E-mail: krtavabe@ut.ac.ir
[2] Department of Irrigation and Reclamation Engineering. Faculty of Agriculture, University of Tehran, Karaj, Iran.

Article Info.

Article type:
Research Article

Article history:
Received: 07 Nov. 2024
Received in revised from: 01 Dec. 2024
Accepted: 16 Dec. 2024
Published online: 27 Dec. 2024

Keywords:
Eutrophication,
Water Transfer,
Physicochemical effects,
Electrical Conductivity,
Parishan Wetland.

ABSTRACT

The international Parishan Wetland, Iran, has completely dried up since 2009. Efforts are underway to restore it through the water transfer from the under-construction Nargesi dam. The aim of this research is to study the physicochemical effects the possibility of eutrophication in this wetland after this function. Sampling was conducted from active springs and the freshwater river (behind the Nargesi dam). The physicochemical parameters were measured and compared with those obtained during wet years. The average electrical conductivity (EC) of the water in the Nargesi dam and the wetland after the water transfer, were calculated considering an annual input of 15 mcm. The results indicated that with transferring during rainy months, after 7-10 years, EC, salinity, hardness, and total dissolved solids (TDS) of the wetland water will reach a similar long-term level as wet years. After this period, if water continues to be supplied from the dam, the salinity of the wetland will increase, reaching a higher level of 0.25-0.27 g/l per year and after 10 years, it will be 2.5-2.7 g/l. However, such changes are not expected to cause significant ecological contradictions in the ecosystem conditions due to the euryhaline nature of aquatic animals of Parishan wetland. Despite the concentration of nitrate and phosphate in the two water sources, due to the high pH and alkalinity of the wetland water, as it was in the wet years, these two nutrients are not limiting factors for production, and according to the high pH and high alkalinity, eutrophication will not occur.

Cite this article: Samadi Kuchaksaraei, B., Rezaei Tavabe, K., Aghajani, M. (2024). Physicochemical Changes and Possibility of Eutrophication by a Water Transfer to International Parishan Wetland, Iran. DESERT, 29 (2), DOI: 10.22059/jdesert.2024.100918

DOI: 10.22059/jdesert.2024.100918

Publisher: University of Tehran Press

1. Introduction

The international Parishan Wetland, located in Fars Province, Iran, with an average area of 4,300-5,000 hectares, has an average depth of 1.2 meters during wet years (University of Tehran, 2021). Positioned in the Helleh Basin (code 2511), this wetland has completely dried up since 2009. Efforts are currently underway to restore it through water transfer from the Nargesi dam (University of Tehran, 2021). To proceed with this action, it is crucial to thoroughly evaluate all aspects and possible risks involved, which may include physical, chemical, and biological ones. As for the transfer plan, the potential physical and biological risks have already been looked into plan (Rezaei Tavabe *et al*., 2021; Rezaei Tavabe & Samadi Kuchaksaraei, 2021). When transferring water between two sources, a crucial consideration is the impact of the source ecosystem's trophic and physicochemical characteristics on the target ecosystem (Wang *et al*., 2018). The medium and long-term physico-chemical effects of transferring water from Nargesi dam to Parishan wetland will be thoroughly analyzed, despite the fact that it is within a basin and between two sub-basins of the Helleh basin. This is because of the unique ecosystem conditions of Parishan wetland and its international importance.

1.1. Eutrophication

Eutrophication is a limnological concept for the process by which a water body is enriched by minerals or nutrients (Harper, 1992; Ansari *et al*., 2010; Due *et al*., 2019; Zamani *et al*., 2025). Aquatic regions that contain a small quantity of nutrients are referred to as oligotrophic, while regions that contain a moderate amount of nutrients are referred to as mesotrophic (Raymont, 2014). Prior to human intervention, the accumulation of nutrients, particularly phosphorus compounds, in water bodies was a gradual process. However, eutrophication caused by human activities is a much faster process, as nutrients are introduced into water resources through various sources of pollution, such as sewage treatment plants, industrial and agricultural wastewater. This phenomenon has a specific impact, which is the harmful algal blooms (HAB) that can ultimately lead to the destruction of the water ecosystem (Chislock *et al*., 2013). After the bacterial decomposition of algae, this process will decrease the oxygen content of the water (Vallentyne & Schindler, 2008; Raymont, 2014).

Eutrophication is the process of increasing the production of biomass in a body of water by accumulating herbaceous nutrients, such as phosphorus, nitrate, or other nitrogen compounds. This increase in nutrients leads to a rise in the abundance of plants, including macrophytes and planktons. As more plants become available as a food source, it enhances the population of herbivores and carnivores feeding on them. (Ansari *et al*., 2010; Wang *et al*., 2018). As the process continues, the aquatic biomass grows, but the biodiversity decreases. In cases of severe eutrophication, excess biomass is destroyed by bacteria, leading to hypoxia due to increased oxygen consumption. The Ullmann Encyclopedia states that the primary limiting factor in eutrophication is phosphate. The presence of phosphorus promotes the excessive growth and decay of plants, particularly simple algae and planktons, which results in a significant decline in water quality (Khan & Mohammad, 2014). Although, some studies have considered nitrogen as a limiting nutrient for increasing algal density (Khan & Ansari, 2005). In wetlands, this lack of oxygen, can lead to the death of fish, and dead algae and organic matter accumulate in the bed and cause anaerobic decomposition and the production of greenhouse gases such as methane and carbon dioxide. Eutrophication cause widely effects on both biological parameters (living organisms) and abiotic parameters such as nutrients (nitrate and phosphate), dissolved oxygen, oxygen demand (BOD, COD) and transparency.

1.2. Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Salinity

The dissolution of materials from geological formations and their entry into water sources, is the reason for impurities to enter water, which affect many chemical characteristic of water and its quality properties. In Iran, there are three main types of formations: limestone, salt and gypsum-marl formations (Heidari *et al*., 2011; Gorbani, 2013), which can cause water to become hard, saline, or sulfated respectively. These formations dissolve in water and introduce impurities and dissolved solids in the form of positive ions (cations) and negative ions (anions). Calcareous formations, introduce compounds and ions based on carbonate and bicarbonate (Rogerson *et al*., 2017), salt formations, introduce chloride based compounds and ions (Hamlin, 2006; Granato *et al*., 2015), and gypsum formations, introduce compounds based on sulfate into the water (López-Buendía *et al*., 2007; Wu *et al*., 2013; Porowski *et al*., 2019). As soon as these substances enter water and are ionized by polar water molecules, they become dehydrated, and for this reason, in the state of ionization and water coverage, water converts into an electrically conductive fluid. The property of water that is related to this transformation is called electrical conductivity (EC), which is a practical property due to its ease of measurement. The total amount of water-soluble substances, including mineral salts and a small amount of organic matter dissolved in water - which can also enter water from geological formations (Ghasemi & Taghavi, 2016) - is known as total dissolved solids (TDS) is measured in milligrams per liter (World Health Organization & International Program on Chemical Safety, 1996) and numerically has a direct relationship with the amount of EC (Rebello *et al*., 2020).

There are two groups of salts, namely carbonates and sulfates. These salts have limited solubility because of their molecular weight. Additionally, their solubility chemical reaction becomes saturated and reciprocating fast. As a result, their effect on water is less and causes less concern. On the other hand, chloride-based salts, which include sodium chloride and potassium chloride, have a high solubility coefficient and due to their mono-capacity, their saturation level is also high, and therefore, the impact of salinity on the ecosystem is much greater than that of other physicochemical factors of water (Eriksson, 1985; Worch, 2015).

Therefore, it is crucial to consider changes in salinity in the destination ecosystem when transferring water from Nargesi dam to Parishan wetland, in addition to modeling changes in EC and dissolved solids. There have been few physicochemical studies conducted in Parishan wetland, some notable ones include the study of heavy metals in wetland sediments (Elmizadeh *et al*., 2017; Karimian Torghabeh *et al*., 2020) and the assessment of their susceptibility to wind erosion (Karami *et al*. 2021). Additionally, the primary production of phytoplankton (Dehghani *et al*., 2008) has been estimated, and the primary conditions of Parishan wetland have been described (Department of Environment UNDP/GEF, 2010; Lotfi 2011). In addition, in previous researches, it has been emphasized on the restoration of Parishan wetland by the management of stray runoff (Isaei & Isaei, 2014) and flood transfer (Isaei & Isaei, 2015). The transfer of water from Nargesi dam to Parishan wetland is intended to achieve this objective.

2. Materials and Methods

2.1. Study area

The study area is limited by the Nargesi dam and Parishan wetland. The Nargesi dam is located in the southeast of this dried wetland (Fig1). Parishan wetland is located in the semi-arid region of Iran, which has moderate and short winters and long, hot, and dry summers. The rainfall regime of this area follows the Mediterranean regime, and the majority of precipitation occurs during the autumn to spring months, while the summer months are generally dry. The average temperature ranges from less than 8 degrees Celsius in the northern highlands to over 24 degrees Celsius in the western parts. The long-term average annual precipitation for the Parishan basin is 463 mm. The annual evaporation rate varies from less than 2400 millimeters in the northern highlands to over 2500 millimeters in the lower areas (Fars Regional Water Authority, 2016).

2.2. Field visits to measure water quality parameters

A field visit to the site of Nargesi dam and Parishan wetland was conducted by the research team in August 2020. Sampling was done from the active springs of Parishan wetland, including Jamshidi, Halak, Imamzadeh Khezr and Qaleh Narenji springs, as well as Shirinrood River (behind Nargesi dam) In order to measure the physicochemical parameters of the water. Although there are many springs in Parishan basin, most of which are now dry with no water for sampling. The qualitative parameters of water were mesured: pH by HACH device, biological oxygen demand (BOD) by digital BOD meter of Hana USA, chemical oxygen demand (COD) by open reverse distillation method, phosphate content (PO_4) under acidic conditions by reaction with ammonium hepta molybdate, nitrate (NO_3) by reduction with cadmium and then reaction with sulfanilic acid (Eaton, 2005). Analysis and measurement of total dissolved solids (TDS), salinity and electrical conductivity (EC) were performed by digital multimeter, and reduction oxidation parameter (ORP) was measured by digital ORP meter and the resulting graphs were plotted. The geographical coordinates of the sampling stations are shown in Table 1.

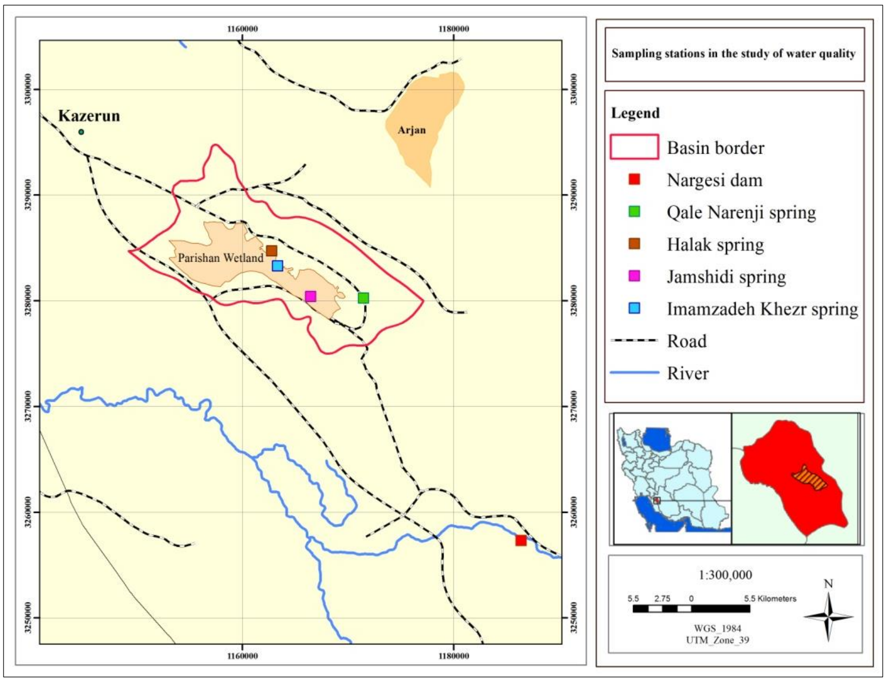


Fig. 1. Sampling points in the in the study of water quality in Parishan wetland basin and Nargesi dam

2.3. Field visit to the salt water spring of FathAbad village (upstream of Nargesi dam)

This visit was conducted in November 2020 by the research team. The salty spring of FatehAbad is located upstream of the Nargesi dam. The salinity of this spring is related to the salt dome of Romeghan, which is located near the FathAbad village in Koohmareh district (Fig. 2). The average flow rate of this spring is approximately 25 l/s. On the way to this spring, a pond has been built by the Fars Regional Water Company, which is an evaporation pond. The purpose of its construction was to collect salt in it and prevent the brine from entering into the river.

Table 1. Geographical coordinates of sampling stations for analysis of physicochemical parameters of water

Station name	Latitude	Longitude
Shirinrood (behind Nargesi dam	29° 15' 32"N	52° 03' 18"E
Imamzadeh Khezr spring	29° 28' 49"N	51° 52' 17" E
Qale Narenji spring	29° 28' 21" N	51° 55' 02" E
Jamshidi spring	29° 28' 43" N	51° 52' 01" E
Halak spring	29° 15' 32" N	52° 03' 18" E

Fig. 2. Location of Romeghan salt dome and its air distance of 13 km with Nargesi dam in satellite image

2.4. Investigating the possibility of eutrophication phenomenon

In order to investigate the possibility of eutrophication, the two factors, nitrate and phosphate, have been considered. In addition to examining the amount of these two factors in the sampling areas, the biochemical cycles of nitrogen and phosphorus, which generally show the process of mineralization and vice versa- becoming organic of the two nutrients: nitrogen and phosphorus by different bacteria. Carbon compound, alkalinity capacity in aquatic ecosystems were also considered (Eriksson, 1985; Worch, 2015). Changes in pH of Parishan wetland water in different months of 2001 (Fig 3), which was previously studied (Dehghani *et al*., 2008), were noted.

In order to analyze the effect of the quality conditions of the source ecosystem on the destination ecosystem, first the quality conditions and EC of the Nargesi dam reservoir were analyzed in case of taking into account the total useful volume of the Nargesi dam reservoir (135 mcm) and considering the amount of water withdrawal in each study period and analyzed. According to the available information, the total useful volume of the Nargesi dam reservoir is 135 million m^3 which on average during a water intake period, 53% of the volume of the reservoir is directly provided from floods (71.55 mcm), 35% in cold and rainy seasons (47.25 mcm) and 12% in warm and agricultural seasons (16.2 mcm), with different EC levels in each of these three sections. On average, the EC of the floodwater behind the Nargesi dam is 820, the river water behind the dam is 2730 in rainy and cold seasons, and 5210 µSiemens/cm in the warm and and agricultural seasons on the river bank upstream of the dam. The average EC of Nargesi dam was obtained using Equation 1:

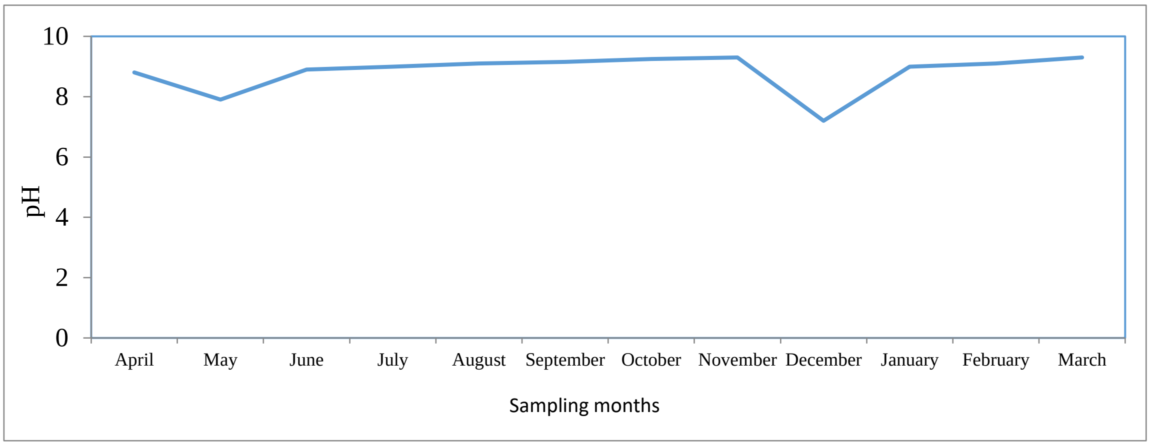


Fig. 3. Changes in pH of Parishan wetland water in different months of 2001 (Dehghani *et al*., 2008)

$$\text{Average of Dam Water EC} = \frac{(EB \times VF) + (EBR \times VR) + (EUW \times VW)}{VDR} \quad (1)$$

EB: Average EC behind the dam
VF: reservoir volume from flood
EBR: EC of river behind the dam in rainy cold seasons
VR: reservoir volume in rainy cold seasons
EUW: EC of river upstream of the dam in warm agricultural season
VW: reservoir volume in warm agricultural season
VDR: Useful volume of the entire dam reservoir

If an average of 15 mcm of water with EC equal to 2015.3 µs/cm is transferred from the Nargesi dam to Parishan wetland per year, the effect of the EC of the dam water with a certain volume on the volume of the wetland water that has different volumes with different sources, should be simulated and analyzed. Although the useful volume of the wetland is 51.6 mcm, the annual average intake of the wetland is much less. Annually, about 13.7 mcm of water enters the wetland through runoff with an average EC of 430 µs/cm, about 6.5 mcm of water enters the wetland through active alluvial and karst springs with an EC of 1120, and the difference between direct precipitation to the wetland surface and potential evaporation is -8.75 mcm. The potential EC is also important, which is 35.2 µs/cm. When the wetland had water, it contained salty compounds, and when it dried up, these compounds penetrated into the soil and a large part of them also entered inside the soil, and if water intake is done, they will also be released which is the potential EC. Therefore, the average EC of wetland water will be calculated according to Equation 2:

$$\text{Average of Wetland Water EC} = \frac{(ER \times VO) + (ES \times VS) + (ED \times VD)}{(EP - DRE)} \quad (2)$$

ER: Average EC of runoff input
VO: Volume of runoff input
ES: EC of active alluvial and karst springs input
VS: Volume of active alluvial and karst springs input
ED: EC of annual water input from Nargesi dam
VD: Volume of annual water input from Nargesi dam
EP: EC potential
DRE: Difference of direct rainfall to the wetland surface and evaporation potential

3. Results

3.1. Results from the analysis of water quality parameters

Results from the analysis of water quality parameters were obtained from sampling the Shirinrood river (behind Nargesi dam) and springs feeding the Parishan wetland in August 2020. Comparison of these results and corresponding graphs indicates that the current water quality of the Shirinrood river differs significantly from that of the Parishan wetland. However, when compared to water-filled years, the Shirinrood's water quality is not significantly different from the wetland. For some water pollution parameters, including nitrate, BOD, and COD, Shirinrood river values are lower than the average for the wetland's wet period. This suggests that Shirinrood water is suitable for transfer to the Parishan wetland via the Nargesi dam. The mid-term and long-term impacts of physicochemical factors from the source water (Nargesi dam) on the destination (Parishan wetland) will be assessed separately in this section.

In this part, the results of the analysis of water quality parameters of the springs of Parishan wetland and Shirinrood river behind Nargesi dam are presented and analyzed. Fig4a shows that the EC in the sampling springs was between 610-1020 µs/cm, which is much lower than the average EC of Parishan wetland in the wet years (5110 µs/cm). Also, the electrical conductivity of Shirinrood river, located behind Nargesi dam, is higher than both the springs of the wetland and the average of the wet years (5270 µs/cm). According to Fig4b, the average salinity of the springs was at most 0.15 g/l, while the average salinity of Parishan wetland in wet years was 2.02 and the average salinity of Shirinrood river in summer and August was 2.11 g/l, which is higher than the values recorded in both the springs and the wetland during wet years.

According to Fig4c, the average nitrate in the springs of Parishan wetland is between 0.4-1.1 mg/l, which is much lower than the average nitrate level in the wet years (6.84 mg/l). Also, the concentration of nitrate in the Shirinrood river, which is 5.9 mg/l, is lower than the average of Parishan wetland, but much higher than the springs. Fig4d shows the average phosphate concentration in the sampling sites. This concentration in springs is between 0.04 to 0.1 mg/l, which is lower than the average of that of wetland in wet years (0.18 mg/l). The concentration of phosphate in Shirinrood river (0.2 mg/l) is higher than the average of Parishan wetland and its springs. Based on Fig4e, the concentration of total dissolved solids (TDS) in the springs leading to Parishan wetland, is between 300 to 500 mg/l, with a significant difference compared to the average wet years (2553 mg/l). However, the concentration of TDS of Shirinrood river is higher than the average of wet years (2640 mg/l). Also, a visit to the salt spring of Fath-abad village upstream of the Nargesi dam, showed that despite the construction of the evaporation pond, there is still about 3-4 l/s of drainage water still flows towards the river.

Fig4f shows the average pH at the sampling stations and their comparison with the average pH during the wetland's water-filled period. The highest pH (7.9) corresponds to the spring of Imamzadeh Khezr, which is higher than the average pH of wet years (7.8). The pH of the Shirinrood River is 7.6. According to Fig4g, the biological oxygen demand (BOD) is low in the springs (5-10 mg/l), but it is significantly higher in the wet years (41 mg/l). However, this parameter in the Shirinrood River is lower than the wetland's and is equal to 35 mg/l. Based on Fig4h, the average chemical oxygen demand (COD) in the springs is between 16 and 21 mg/l, and in the wetland, it was 73 mg/l on average in the wet years. This factor in the Shirinrood River is lower than that of the wetland in wet years and is equal to 68 mg/l. Fig4i shows the average ORP at the sampling stations, but there is no data available for this parameter regarding the wet years of the Parishan Wetland. Accordingly, the ORP level in the springs was between 180 and 238 mV, and in the Shirinrood River, it was slightly higher at 246 mV.

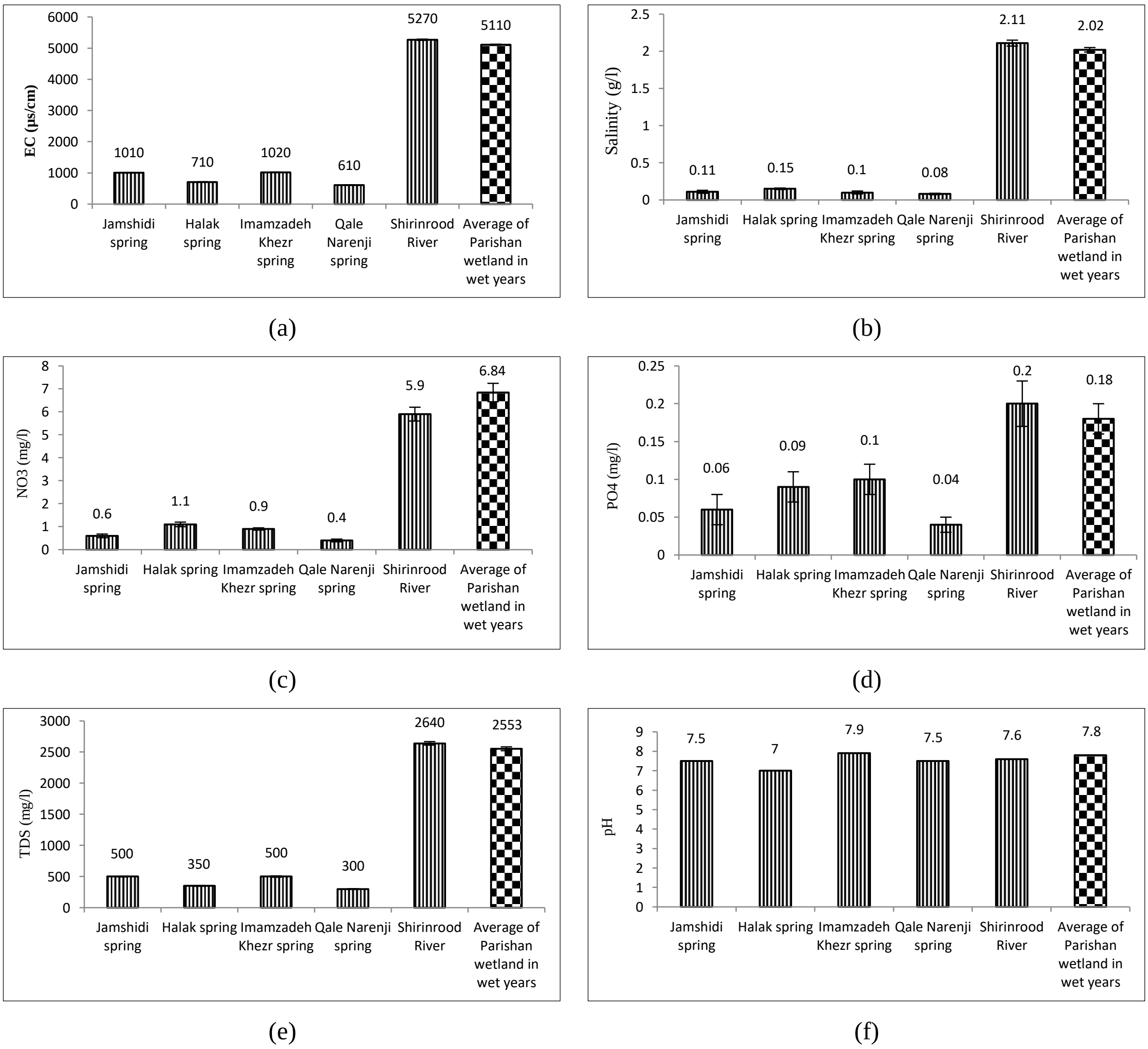
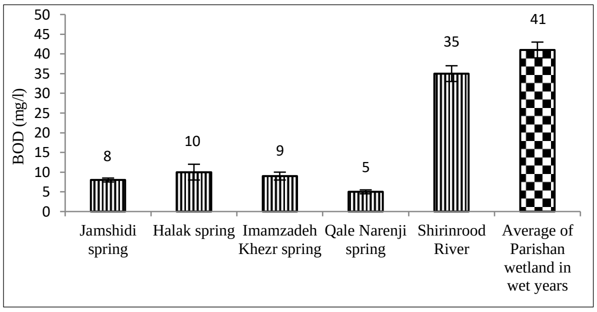
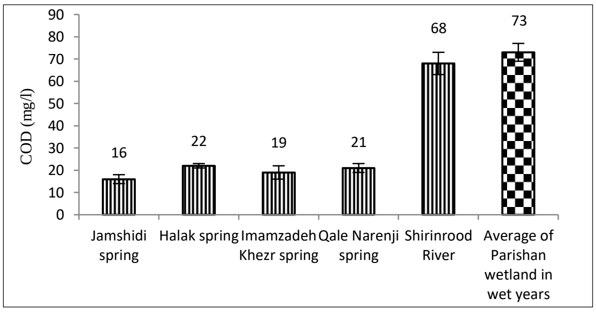


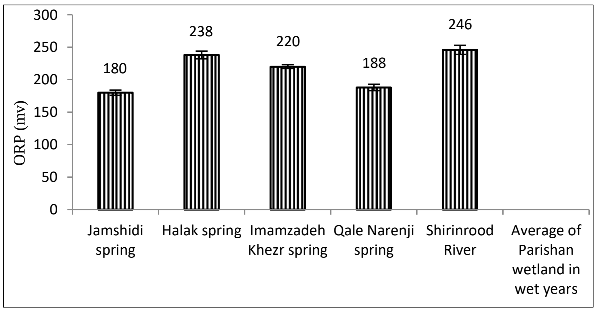
Fig. 4. a) Mean electrical conductivity (EC); b) Average salinity; c) Average nitrate; d) Average phosphate; e) Average TD; f) Average pH in sampling springs of Parishan wetland, Shirinrood river (behind Nargesi dam) along with Parishan long-term average



(g)



(h)



(i)

Fig. 4. Continued. g) Average BOD; h) Average COD; i) Average ORP in sampling springs of Parishan wetland, Shirinrood river (behind Nargesi dam) along with Parishan long-term average

According to a field visit conducted in August 2019 to the Jamshidi, Halak, Imamzadeh Khezr, and Qaleh Narenji springs (which are Parishan wetland springs) as well as the Shirinrood River, the average EC in the sampled springs was between 610-1020 µs/cm. This is significantly lower than the average EC of the Parishan wetland during wet years, which was 5110 µs/cm. additionally, the electrical conductivity of the Shirinrood River in this season is higher than both the springs and the average of wet years (5270 µs/cm). According to Fig4b, the average salinity of the springs was at most 0.15 g/l, while the average salinity of the Parishan wetland during wet years was 2.02 g/l, and the average salinity of the Shirinrood River in August was 2.11 g/l. This is higher than both the springs and the wetland during wet years. Based on the information provided in Equation 1, the calculated average EC of the dam reservoir water is 2015.3 µs/cm.

$$\text{Average of Dam Water EC} = \frac{(820\times71.55)+(2730\times47.25)+(5210\times16.2)}{135} = 2015.3$$

The simulated mathematical equation model for the EC of the Nargesi dam reservoir water and the conditions of its impurity compounds is as follows, calculated through the formation of simplex tables and boards, confirming the above answer

Min: $Z = 6X1+3X2+X3$

S.T.: $1.8X1+X2\geq5$

$2X2+X3\geq1.4$

$X3\geq0.3$

In this model:

X1: Chloride-based monovalent impurities and ions (salinity factors)

X2: Carbonate-based divalent impurities and ions (hardness factors)
X3: Sulfate-based impurities and divalent ions (sulfate factors)
According to Equation 2, with the annual entry of 15 mcm of water from the Nargesi dam with an EC of 2015.3 µs/cm, the calculated average EC of the wetland water is 1640.8.

$$\text{Average of Wetland Water EC} = \frac{(430\times13.7)+(1120\times6.5)+(2015.3\times15)}{(35.2-8.75)} = 1640.8$$

4. Discussion

The sharp decline in the underground water level of the Parishan wetland began at the start of the last two decades, leading to a significant decrease in the lake's area (Shafiei *et al*., 2017). The wetland's water volume is significantly correlated with the underground water level and water extraction from wells surrounding the wetland (Jahanbakhsh Ganjeh *et al*., 2017). Preventing illegal and unauthorized harvesting of underground water sources, determining environmental water rights for dams, altering cultivation patterns, implementing new irrigation methods, and changing the livelihoods of local communities are all considered strategies for dried wetlands. However, it should be noted that today, with ongoing droughts, severe reductions in precipitation, rising average air temperatures, and consequent increased evaporation, combined with depleted aquifers and low-water rivers, the effectiveness of these prescriptions will be diminished, at least in the short term (Isaei & Isaei, 2014). Therefore, managing stray runoff and transferring runoff water to the wetland is a way to restore it, while other methods may be ineffective in the short term (Jordan *et al*., 2003; O'geen *et al*., 2010; Isaei & Isaei, 2014; Isaei & Isaei, 2015). Consequently, transferring water from the Nargesi dam to the Parishan wetland is on the agenda of the Fars Province Department of Environment (University of Tehran 2021). This research investigates the potential effects of this transfer on eutrophication and EC changes in the wetland.

4.1. The possibility of creating the phenomenon of eutrophication

In aquatic ecosystems, production and trophic levels involve the conversion of inorganic carbon or carbon dioxide (CO_2) into organic carbon and plant biomass through photosynthesis by phytoplankton and higher aquatic plants as primary producers. This organic matter is then distributed throughout the ecosystem by secondary consumers in the food chain (Harper, 1992; Raymont, 2014). To create conditions of eutrophication and overnutrition, nitrates and phosphates are primarily responsible as the main limiting factors for production and trophic levels in water resources (Ansari *et al*., 2010; Ngatia *et al*., 2019; Bravo de Guenni *et al*. 2024). Nitrate and phosphate are the two most important factors contributing to eutrophication in stagnant aquatic ecosystems like wetlands. These nutrients function as production-limiting factors in aquatic ecosystems. The rising concentration of nutrients caused by human activities, is a critical global environmental issue threatens the functional integrity of aquatic ecosystems (Fielding *et al*., 2020; Wu *et al*., 2021; Lin *et al*., 2021). Notably, phosphate is considered a production-limiting factor in freshwater ecosystems (Harper, 1992; Sterner, 2008; Beusen *et al*., 2016), while nitrate is considered one in brackish and saline water sources (Howarth & Marino, 2006; Mills *et al*., 2018). These two production-limiting nutrients primarily enter aquatic ecosystems through agricultural, industrial, urban, and domestic wastewaters. In the biochemical nitrogen cycle, denitrification by bacteria converts a significant portion of nitrate in the aqueous medium into gaseous nitrogen (N_2) and gaseous nitrogen oxide (N_2O), removing it from the aqueous environment.

This process is crucial for maintaining nitrogen concentration balance in the environment, especially in wetland ecosystems (Ansari *et al*., 2010; Raymont, 2014).

The biochemical phosphorus cycle is relatively simple due to the absence of intermediate compounds. It primarily involves two main compounds: organic phosphorus (as biomass) and inorganic phosphate in the aqueous medium. Inorganic phosphate, a limiting factor for production in freshwater ecosystems, is rapidly absorbed by phytoplankton and higher plants. It is then stored in living organisms, which are highly diverse in wetland ecosystems, resulting in fewer associated problems and increased trophic levels (Harper, 1992; Eriksson, 1985; Worch, 2015). Based on measurements and obtained data, the nitrate concentration in the Shirinrood River is 5.9 mg/l, while it was 6.84 mg/l during the wetland's full water periods (Fig4c). Similarly, the phosphate concentration in the Shirinrood River is 0.2 mg/l, compared to 0.18 mg/l in the wetland's wet years (Fig4d). These nutrients primarily enter the water through agricultural wastewater, and their concentrations fluctuate throughout the year based on agricultural activities and fertilization levels. Both nitrate and phosphate concentrations are within the range suitable for phytoplankton activity and trophic levels in the Parishan wetland. Normally, these conditions would promote eutrophication and nutrient enrichment; however, this has not occurred in the past or during wet years, and is unlikely to occur in the future with water intake from the Nargesi dam. The reason is the wetland water's high pH and alkaline capacity, which ranges from 8 to 9 during most months of the year (Fig3 and Fig4f).

The high pH in Parishan wetland is attributed to the alkaline capacity of carbonate ions, which have entered the wetland in solution form from Asmari limestone formations (Sadeghi *et al*., 2011). These ions significantly contribute to the wetland's TDS, EC, and alkalinity. On the one hand, the high pH has limited the activity and binary fission of unicellular phytoplankton. On the other hand, carbon compounds exist in the form of CO_2 within this pH range (Ansari *et al*., 2010; Verspagen *et al*., 2014; Worch, 2015). Therefore, CO_2 levels are low in the aquatic environment, reducing the potential for photosynthetic reactions. This contributes to the wetland's maintenance in oligotrophic and mesotrophic conditions. In fact, in aquatic environments where dissolved materials from calcareous formations are introduced, increasing alkalinity and pH, the limiting factor for production shifts from nutrients to pH itself. This is because over nutrition and eutrophication typically occur in acidic environments (Harper, 1992; Bellemakers & Maessen, 1998; Raymont, 2014). Based on these analyses, transferring water from the Nargesi dam to the Parishan wetland will not result in eutrophication or over nutrition, and there are no concerns in this regard. Over the long term, the Parishan wetland has gradually tended towards mesotrophic conditions but has never entered a eutrophic state (Dehghani *et al*. 2008). Also, based on Figures 4 (c, d, g, h), the parameters related to water's biological, ecological, nutrient, and ecosystem conditions, including nitrate, phosphate, BOD, and COD, are lower in the Shirinrood River compared to the average values during the Parishan wetland's wet years. In cases where the Shirinrood River values are higher, the difference is not significant. These analyses indicate that transferring water from the Nargesi dam to the Parishan wetland is unlikely to induce eutrophication, thereby minimizing the risk of ecosystem conflict in terms of water quality and eutrophication. Additionally, this research proposes a pipe-based water transfer system, eliminating the risk of soil erosion and organic matter transfer that could contribute to sedimentation and eutrophication (University of Tehran, 2021).

4.2. Ability to make EC changes

Based on measurements and data collected in this research, nitrate and phosphate concentrations in the Parishan wetland are at appropriate levels to increase trophic intensity. However, this has not occurred in water-filled years due to the wetland's high pH and alkaline capacity, caused by carbonate ions from the Asmari limestone formation (Sadeghi *et al*., 2011), and will likely not occur in the future for the same reasons. Additionally, Dehghani *et al*. (2008) classified this wetland as oligo-mesotrophic. The lower EC levels observed in April (Fig3) may be attributed to limited rainfall during that month. According to the results of this research, three sources of impurity compounds affecting EC will mix when water is transferred. These sources are: the EC of the transferred water from the Nargesi dam, the EC of the wetland input, and the salts and compounds that have settled and deposited in the wetland bed over the past few years. Since the water source dried up, a large portion of total dissolved solid compounds, particularly monosaccharide salts, has been removed from the wetland bed due to factors such as molecular weight, wind erosion, groundwater infiltration, and absorption by saline-tolerant plants. These plants are subsequently harvested by grazing livestock or local communities. As a result, the amount of impurities and potential EC in the wetland bed has decreased by approximately 50% over the past 10 years of drying. Since the lake water's EC was 5110 during wet years, the current EC potential of the bed salt is approximately 2555. This salt primarily consists of large carbonate and sulfate ions, not salt and chloride ions, which have lower leaching power and are less susceptible to wind erosion. If water is transferred from the Nargesi dam, this potential EC will dissolve into the wetland water, directly affecting the lake's actual EC.

Based on the aforementioned explanations and simulations, after introducing 15 million m^3 of water from the Nargesi dam to the wetland, as outlined in the Parishan wetland restoration project (University of Tehran, 2021), and subsequent groundwater compensation to reach the bed's zero level, the wetland's EC, salinity, and hardness will reach their long-term range within 7-10 years. This timeframe is contingent upon annual groundwater extraction for agriculture, annual rainfall, spring inflow, and surface evaporation. During this period, the wetland should be restored to its ecological level by managing water consumption, input, and output. After this period, if water transfer from the Nargesi dam continues, the wetland water will become 0.27-2.5 g/l saltier per year. Even if this transfer continues for another 10 years, the wetland's salinity will increase by only 2.5-2.7 g/l. Since TDS and salinity levels are directly correlated with EC changes, the simulated conditions for EC can also be extrapolated to predict changes in TDS and salinity. Due to the euryhaline nature of phytoplankton, zooplankton, fish, and plants in the wetland, these medium and long-term changes in the wetland water's physicochemical conditions are unlikely to have significant negative exosystemic impacts on the living conditions and ecosystem of the wetland itself.

Despite the construction of an evaporation pond by the Fars Province Regional Water Company to intercept the salty spring, 3-4 liters per second of water still flows into the river. This has a significantly negative impact on the river due to its high salinity and composition of single-capacity ions, which are near saturation levels. The Ministry of Energy, the dam construction company, and the Fars Province Regional Water Company must collaborate to fully manage this area and prevent the spring water from entering the river. This could be achieved by transferring the water through pipes to a downstream location for salt management and extraction. While the Romeghan salt dome will have a long-term impact on the river, the river does not significantly affect the salt dome. However, the Fatehabad saltwater spring in this area directly impacts the river.

5. Conclusion

The NO_3 and PO_4 concentrations in Shirin-rood water, is less than wetland's full water periods. The high pH and high alkaline capacity, also indicate that this transferring will not result in eutrophication or over nutrition in Parishan wetland. The high pH in Parishan wetland is due to the alkaline capacity of carbonate ions entered the wetland from Asmari calcareous formations and create a large part of TDS, EC and the alkalinity of the lake. High pH, limits the activity of phytoplankton, maintaining wetland in oligotrophic and mesotrophic conditions. By transferring of water from Nargesi dam to Parishan wetland, eutrophication and over nutrition will not occur. Since the EC of the lake water was 5110 µs/cm during the wet years, the current EC potential of the bed salt is about 2555 µs/cm, which are mainly large ions of carbonate and sulfate, with less leaching power. By entering 15 mcm of water into the wetland from Nargesi dam, and groundwater compensation, after 7-10 years, EC, salinity and hardness of the wetland will reach the long-term range of the wetland. Then, if the transfer continues, the water of the wetland will be 0.27-25 g/l saltier per year, after 10 years, and the salinity will be only 2.5-2.7 g/l more than before. Due to the euryhaline organisms, it will not have significant negative exosystemic effects on the living conditions and ecosystem of the wetland itself.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by "Bahareh Samadi Kuchaksaraei", "Kamran Rezaei Tavabe" and "Maryam Aghajani". Field visits and sampling was performed by "Kamran Rezaei Tavabe". Preparation of maps and figures was carried out by "Bahareh Samadi Kuchaksaraei". The first draft of the manuscript was written by "Bahareh Samadi Kuchaksaraei". Reviewing and English editing was performed by "Maryam Aghajani", and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability

Data that support the results of this study are available from the corresponding author upon reasonable request.

Acknowledgment

The authors, thank the cooperation of the Fars Province Department of Environment, Environmental NGO of "*Miras Parishan*" and the local community of the Parishan Wetland Basin.

Ethical considerations

The study was approved by the Ethics Committee of the University of ABCD (Ethical code: IR.UT.RES.2024.500). The authors avoided from data fabrication and falsification.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflict of interest

The authors have no relevant financial or non-financial interests to disclose.

References

Ahmadianfar, I., Jamei, M. and Chu, X. (2020). A novel Hybrid Wavelet-Locally Weighted Linear Regression (W-LWLR) Model for Electrical Conductivity (EC) Prediction in Surface Water. *Journal of Contaminant Hydrology 232*, p.103641. https://doi.org/10.1016/j.jconhyd.2020.103641

Ansari, A. A., Singh, G. S., Lanza, G. R. and Rast, W. eds. (2010) Eutrophication: causes, consequences and control (Vol. 1). *Springer Science & Business Media*.

Bellemakers, M. J. S., Maessen, M. (1998). Effects of Alkalinity and External Sulphate and Phosphorus Load on Water Chemistry in Enclosures in an Eutrophic Shallow Lake. *Water, Air, & Soil Pollution. 101*: 3–13. DOI: https://doi.org/10.1023/A:1004954928604

Beusen, A. H. W., Bouwman, A. F., Van Beek, L. P. H., Mogollon, J. M., Middelburg, J. J. (2016). Global riverine N and P transport to ocean increased during the 20th century despite increased retention along the aquatic continuum. *Biogeosciences 13*:2441–2451. https://doi.org/10.5194/bg-13-2441-2016

Bravo de Guenni, L., Lenczewski, M., Mallow, S.V., Solanki, S. (2024). Assessing water quality spatial heterogeneity from multiple pollution sources in the Boung Cheung Ek Wetland, Phnom Penh. *Cambodia Water, 16*(1):4.

Chislock, M. F., Doster, E., Zitomer, R. A. and Wilson, A. E. (2013). Eutrophication: causes, consequences, and controls in aquatic ecosystems. *Nature Education Knowledge. 4*(4), p.10.

Dehghani, A., Monfared, N., Yeganeh, V., Avakh Keysami, M., (2008). Phytoplankton diversity in Parishan wetland. The first regional conference on inland aquatic ecosystems in Iran, Boushehr. https://civilica.com/doc/124351 (In Persian)

Department of Environment UNDP/GEF (2010). Lake Parishan Management Plan. 51 p. (In Persian). http://www.wetlandsproject.ir/publications/books/detail/Lake-Parishan-Management-Plan/1008/view/

Du, H. B., Chen, Z. N., Mao, G. Z., Chen, L., Crittenden, J,, Li, R. Y. M., Chai, L. H. (2019). Evaluation of eutrophication in freshwater lakes: a new non-equilibrium statistical approach. *Ecol Indicat 102*: 686–692. https://doi.org/10.1016/j.ecolind.2019.03.032

Elmizadeh, H., Farhadi, S., and Razmi, M. (2017). Estimates of heavy metals pollution in Parishan wetland sediments using pollution indices. *Environmental Sciences. 15* (1): 61-76.

Eriksson, E. (1985). *Principles and Applications of Hydrochemistry*. Springer Netherlands. DOI: 10.1007/978-94-009-4836-5

Fars Regional Water Authority. (2016). Updating the balance of water resources from study areas of Helleh basin and small canals on both sides leading to 2010-2011. Volume 5: Water Resources Assessment, Water Resources Balance Report, Parishan Lake Studies Area. Ministry of Energy, Iran Water Resources Management Company (In Persian).

Fielding, J. J., Croudace, I. W., Kemp, A. E. S., Pearce, R. B., Cotterill, C, J., Langdon, P., Avery, R. (2020). Tracing lake pollution, eutrophication and partial recovery from the sediments of Windermere, UK, using geochemistry and sediment microfabrics. *Sci Total Environ 722*:137745. https://doi.org/10.1016/j.scitotenv.2020.137745

Ghasemi, F., Taghavi, L. (2016). Effect of environmental geology impacts on quality and quantity of aquifers (case study: groundwater reservoirs in Akhtarabad village, Malard county). *Iranian Journal of Environmental Geology. 10* (36): 56-82. (In Persian)

Ghorbani, M. (2013). *A summary of geology of Iran. In The economic geology of Iran* (pp. 45-64). Springer, Dordrecht.

Granato, G. E. DeSimone, L. A., Barbaro, J. R. and Jeznach, L. C. (2015). *Methods for evaluating potential sources of chloride in surface waters and groundwaters of the conterminous United States* (No. 2015-1080). US Geological Survey.

Hamlin, H. S. (2006). Salt domes in the Gulf Coast aquifer. Aquifers of the Gulf Coast of Texas, Mace, RE, Davidson, SC, Angle, ES, and Mullican, WF, eds., Texas Water Development Board, Report, 365: 217-230.

Harper, D. M. (1992). *Eutrophication of freshwaters* (p. 327). London: Chapman & Hall.

Heidari, M., Khanlari, G. R., Beydokhti, A. T. and Momeni, A. A. (2011). The formation of cover collapse sinkholes in North of Hamedan, Iran. *Geomorphology*, *132*(3-4): 76-86. https://doi.org/10.1016/j.geomorph.2011.04.025

Heydari, M., Olyaie, E., Mohebzadeh, H., Kisi, Ö. (2013). Development of a neural network technique for prediction of water quality parameters in the Delaware River, Pennsylvania. *Middle-East J. Sci. Res. 13* (10): 1367–1376. DOI:10.5829/idosi.mejsr.2013.13.10.1238

Howarth, R. W. and Marino, R, (2006), Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades. *Limnology and Oceanography, 51*(1part2): 364-376. DOI: https://doi.org/10.4319/lo.2006.51.1_part_2.0364

Isaei, A. R. and Isaei, M. (2014). Restoration of Parishan wetland by management of wandering runoff, Conference on Climate Change and a route to a Sustainable Future, Tehran (In Persian). https://civilica.com/doc/269491

Isaei, A. R. and Isaei, M. (2015). Flood transfer, the way to save Parishan lake, International Conference on Research in Engineering. Science and Technology. https://civilica.com/doc/398166

Jahanbakhsh Ganjeh, M., Khorasani, N., Morshedi, J., Danehkar, A, and Naderi, M. (2017). An Investigation on Spatial Changes of Parishan International Wetland Using Remote Sensing Methods. *Applied Ecology and Environmental Research. 15* (3): 549-562. DOI: 10.15666/aeer/1503_549562

Jordan, T. E., Whigham, D. F., Hofmockel, K.H. and Pittek, M. A. (2003). Nutrient and sediment removal by a restored wetland receiving agricultural runoff. Journal *of environmental quality, 32*(4): 1534-1547.

Karami, E., Zehtabian, G., Khosravi, H., Mesbahzadeh, T., Zareh, S. and Behrang Manesh, M, (2021), Determination of lake sediments susceptibility to wind erosion and its role in dust formation (Parishan lake, Fars province). *Researches in Earth Sciences, 12* (1):114-130.

Karimian Torghabeh, A., Afzali, S. F., Jahandari, A., Mahmudy Gharaie, M. H. and Al-Khashman, O. A. (2020). Evaluation of trace elements concentration in surface sediments of Parishan International Wetland (Fars Province, SW Iran) by using geochemical and sedimentological analysis. *Toxin Reviews*, 1-11. DOI: https://doi.org/10.1080/15569543.2020.1737825

Khan, F. A. and Ansari, A. A. (2005). Eutrophication: An Ecological Vision. *Botanical Review, 71* (4): 449–482. doi:10.1663/0006-8101(2005)071[0449:EAEV]2.0.CO;2

Khan, M. N. and Mohammad, F. (2014). *Eutrophication of Lakes*. in Ansari, Gill, SS (eds.), Eutrophication: Challenges and Solutions; Volume II of Eutrophication: Causes, Consequences and Control, Springer Science+Business Media Dordrecht. doi:10.1007/978-94-007-7814-6_1

Lin, S. S., Shen, S. L., Zhou, A., Lyu, H. M. (2021). Assessment and management of lake eutrophication: a case study in Lake Erhai, China. *Sci Total Environ 751*:141618. https://doi.org/10.1016/j.scitotenv.2020.141618

López-Buendía, A. M., Whateley, M. K. G., Bastida, J. and Urquiola, M. M. (2007), Origins of mineral matter in peat marsh and peat bog deposits. Spain. *International Journal of Coal Geology, 71* (2-3): 246-262. https://doi.org/10.1016/j.coal.2006.09.001

Lotfi, A. (2011). Lake Prishan Concise Baseline Report, Department of Environment, UNDP/GEF. 113 p (In Persian). http://www.wetlandsproject.ir/publications/books/detail/Lake-Parishan-Consice-Baseline-Report/1007/view

Menberu, Z., Mogesse, B. and Reddythota, D. (2021). Evaluation of water quality and 342utriphication status of Hawassa Lake based on different water quality indices. *Applied Water Science, 11*(3): 1-10. https://doi.org/10.1007/s13201-021-01385-6

Mills, M. M., Brown, Z. W., Laney, S. R., Ortega-Retuerta, E., Lowry, K. E., Van Dijken, G. L. and Arrigo, K. R. (2018). Nitrogen limitation of the summer phytoplankton and heterotrophic prokaryote communities in the Chukchi Sea. *Frontiers in Marine Science, 5*, p.362. DOI: https://doi.org/10.3389/fmars.2018.00362

Ngatia, L., Grace, III. J. M., Morias, D. and Taylor, R. (2019). Nitrogen and phosphorus eutrophication in marine ecosystems. *Monitoring of Marine Pollution*, pp.1-17.

O'geen, A. T., Budd, R., Gan, J,, Maynard, J. J., Parikh, S.J. and Dahlgren, R..A. (2010). Mitigating nonpoint source pollution in agriculture with constructed and restored wetlands. *Advances in agronomy, 108*: pp.1-76.

Porowski, A., Porowska, D. and Halas, S. (2019). Identification of sulfate sources and biogeochemical processes in an aquifer affected by Peatland: Insights from monitoring the isotopic composition of groundwater sulfate in Kampinos *National Park, Poland. Water, 11*(7): p.1388. https://doi.org/10.3390/w11071388

Raymont, J. E. (2014). *Plankton & productivity in the oceans: Volume 1: Phytoplankton*. Elsevier.

Rebello, L. R. B., Siepman, T. and Drexler, S. (2020). Correlations between TDS and electrical conductivity for high-salinity formation brines characteristic of South Atlantic pre-salt basins. *Water SA, 46*(4): 602-609. DOI: 10.17159/wsa/2020.v46.i4.9073

Rezaei Tavabe, K. and Samadi Kuchaksaraei, B. (2021). Investigation of the possibility of invasive species entering Parishan wetland due to water transfer from Nargesi dam by studying the biodiversity of Parishan wetland and Dalaki river. 1st Fars Biodiversity Conference, March 2021, Shiraz University, Iran (Main text in Persian).

Rezaei Tavabe, K., Samadi Kuchaksaraei, B. and Zare, G. (2021), Investigation of biological indicators and flagship species in determining the ecological water right of Parishan wetland. 1st Fars Biodiversity Conference, March 2021, Shiraz University, Iran (Main text in Persian).

Rogerson, M., Mercedes-Martín, R., Brasier, A. T., McGill, R. A., Prior, T. J., Vonhof, H., Fellows, S. M., Reijmer, J. J., McClymont, E., Billing, I. and Matthews, A. (2017). Are spherulitic lacustrine carbonates an expression of large-scale mineral carbonation? A case study from the East Kirkton Limestone, *Scotland. Gondwana Research, 48*: 101-109. https://doi.org/10.1016/j.gr.2017.04.007

Sadeghi, R., Vaziri-Moghaddam, H. and Taheri, A. (2011). Microfacies and sedimentary environment of the Oligocene sequence (Asmari Formation) in Fars sub-basin, Zagros Mountains, southwest Iran. *Facies, 57* (3): 431-446. https://doi.org/10.1007/s10347-010-0245-x

Schindler, D., and Vallentyne, J. R. (2008). *Over fertilization of the World's Freshwaters and Estuaries*, University of Alberta Press, 348 p.

Shafiei, M., Raini, S., Fazloli, R. and Gholami, S. (2017). Investigation of the Effect of Water Removal from Wells Surrounding Parishan Lake on Groundwater and Surface Water Levels. *Environmental Researches, 7*(14): 237-248.

Sterner, R. W. (2008). On the phosphorus limitation paradigm for lakes. *International Review of Hydrobiology, 93* (4-5): 433-445. DOI: https://doi.org/10.1002/iroh.200811068

Tabla-Hernández, J., Rodríguez-Espinosa, P. F., Hernandez-Ramirez, A. G., Mendoza-Pérez, J. A., Cano-Aznar, E. R. and Martínez-Tavera, E. (2018). Treatment of Eutrophic water and wastewater from Valsequillo Reservoir, Puebla, Mexico by Means of Ozonation: A multiparameter approach. *Water, 10* (12): p.1790. https://doi.org/10.3390/w10121790

University of Tehran. (2021). Water transfer studies from Nargesi dam to Parishan wetland; Parishan wetland restoration project, Fars Province department of environment and University of Tehran (In Persian).

Verspagen, J. M., Van de Waal, D. B., Finke, J. F., Visser, P. M., Van Donk, E., and Huisman, J. (2014). Rising CO_2 levels will intensify phytoplankton blooms in eutrophic and hypertrophic lakes. *PloS one, 9*(8), e104325. DOI: https://doi.org/10.1371/journal.pone.0104325

Wang, Y., Hu, W., Peng, Z,, Zeng, Y. and Rinke, K. (2018). Predicting lake 344utriphication responses to multiple scenarios of lake restoration: A three-dimensional modeling approach. *Water*, *10*(8), p.994. https://doi.org/10.3390/w10080994

Worch, E. (2015). *Hydrochemistry; Basic Concepts and Exercises*, In: De Gruyter Textbook. DOI: https://doi.org/10.1515/9783110315561

World Health Organization and International Programme on Chemical Safety. (1996). Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information, 2nd ed. World Health Organization. https://apps.who.int/iris/handle/10665/38551

Wu, N., Liu, S., Zhang, G., Zhang, H. (2021). Anthropogenic impacts on nutrient variability in the lower Yellow River. *Sci Total Environ 755*:142488. https://doi.org/10.1016/j.scitotenv.2020.142488

Wu, S., Kuschk, P., Wiessner, A., Müller, J., Saad, R.A. and Dong, R. (2013). Sulphur transformations in constructed wetlands for wastewater treatment: a review. *Ecological engineering*, *52*, pp.278-289. https://doi.org/10.1016/j.ecoleng.2012.11.003

Zamani-Ahmadmahmoodi, R., Bayati, S., Abdollahi, K., Mafi-Gholami, D., Joorabian Shooshtari, S., Gharahi, N., Raeisi-bidekani, A., Rondigues Maritn, J. A., Soleimanipour, S. S. (2025). Water quality and eutrophication status of the Zarivar Wetland (Iran). *Applied Water Science*, *15*(2), 24.