Study of the Influence of Surface Water and Groundwater Pollution on Aquatic and Marine Life : Ecological and Environmental Approach: The Case of River Guebli in the Tamalous- Plain, Algeria

[1]Abdelaziz Sadoune, [2]Salah Eddine Tachi, [3]Salim Heddam, [4]Asma Ferroum

[1]Department of Geology, Faculty of Earth Sciences Badji Mokhtar-Annaba University P.O.Box 12. Annaba, 23000, Algeria, abdelaziz.sadoune@univ-annaba.dz
[2]Department of Geology, Faculty of Earth Sciences Badji Mokhtar-Annaba University P.O.Box 12. Annaba, 23000, Algeria, salah-eddine.tachi@univ-annaba.dz
[3]Department of agronomy, Skikda University, heddamsalim@yahoo.fr
[4]Department of Geology, Faculty of Earth Sciences Badji Mokhtar-Annaba University P.O.Box 12. Annaba, 23000, Algeria, asma.ferroum@univ-annaba.dz

Received: 09-03-2026 **Accepted**: 19-05-2026 **Published**: 12-06-2026

Abstract
The water in our rivers is becoming dirty.. The environment quality is getting worse. That is a problem for our planet. This study looked at what happened to the water in the Tamalous Plain in Algeria from. We checked the water to see what was in it by looking at particles and metals. They used tools like the Piper diagram and other methods what kind of water it was and if it was good, for growing plants and other lifeWe want to know what is in the water and how it is affecting the living things in the river. So we will check the temperature and other things like pH and how much oxygen is in the water. We also want to know if there are any things like metals and other pollutants in the water.
We are worried about how the pollution's affecting the ; animals and plants that live in the river and in the ocean where the river flows into. We will look at how the living things in the river're responding to the pollution and if they are getting sick or dying.
We will take samples from parts of the river to see where the pollution is coming from and which areas are the most affected. This will help us understand what is happening to the Guebli River and how we can protect it.
The results of this study will help us understand how pollution is affecting the river and the ocean. It will also give us information that we can use to monitor the water quality and prevent pollution. This is important for Algeria and for the world because we need to protect our water and our planet.

Keywords: Guebli River; Tamalous Plain; surface water pollution; aquatic ecosystems; marine ecosystems; environmental quality; ecological assessment; physicochemical parameters; heavy metals; aquatic organisms; environmental monitoring; Algeria.

1.Introuduction
Freshwater resources are facing more pressure from natural causes and human activities especially in Mediterranean areas where changes in the weather more people and more farming make the need for water higher. In these conditions keeping water quality good is a challenge for development that lasts a long time especially in places where surface water and groundwater are important for living and growing crops.
The chemical make-up of water comes from the mix of the rocks, in the area how the water moves and what people do. The breaking down of rocks the way water goes into the ground and the way water and rocks mix naturally control the levels of dissolved minerals.. Farming, building cities and putting waste water into the water can change the water.
chemistry. Understanding these processes is therefore important for evaluating water quality and identifying the factors for its spatial and temporal variability.
Chemistry is a part of understanding water. This is because we need to know how good or bad the water is and what makes it change from one place to another or from one time to another.
To get an idea of water people usually look at lots of things together like the chemicals in the water and how they relate to each other. They use something called the Piper diagram to see what kind of chemicals are in the water and where they are. They also use something called Principal Component Analysis to figure out what is controlling the chemistry of the water and how all the different things in the water are related to each other.
The Water Quality Index is another tool that gives us an idea of how good or bad the water is. Then there are things like the Sodium Adsorption Ratio and Sodium Percentage that help us know if the water is good for irrigation. If it has too much sodium.
The Tamalous Plain is a place where people grow a lot of food. The Guebli River and the water under the ground help give people the water they need.. Because more people are farming and living in the area there is a worry that the water is getting worse. Even though the Tamalous Plain is very important for the economy and for people there is not a lot of study on the water including what is in it and how it changes.

So we need to do a study to understand what is happening with the water and to help make sure we use the water in a way that is good for everyone.
This study looks at how the water in the Tamalous Plain changed from 2023 to 2025. We paid attention to what kind of chemicals are in the water what is controlling the chemistry of the water and if the water is good for irrigation. The study helps us understand the water in the Tamalous Plain and how it changes over time and from one place to another which is important for this farming area in northeastern Algeria.
The water in the Tamalous Plain is very important for chemistry and for people. We need to know more, about the chemistry of the water to help keep it good. The chemistry of the water is what we are trying to understand in this study of the Tamalous Plain.

2. Materials and Methods
2.1 Study Site
The area took place in Tamalous city, which is located in the Skikda Province of Algeria. The Tamalous Plain is part of the Guebli River watershed. This watershed is connected to the Constantinois hydrographic system that flows into the Mediterranean coast. The Tamalous Plain has a landscape and lots of water so people do a lot of farming there. The Tamalous Plain uses groundwater and surface water for irrigation and for peoples needs.
The Tamalous Plain has a Mediterranean climate, which means it has wet winters and hot and dry summers. The amount of rain that falls during times of the year really affects how much water is in the rivers and underground. This means that the weather and what people do affect the quality of the water in the watershed.
If we look at the geology of the Tamalous Plain we can see that it is made up of types of rocks. The Tamalous Plain has layers of rock from the Miocene and Pliocene periods and on top of these layers there are deposits of sand and gravel from the Quaternary period. These deposits of sand and gravel are where the main aquifer of the Tamalous Plain is located. The layers of rock underneath from the Miocene and Pliocene periods are not very permeable which means they control how groundwater moves and is stored. The geology of the Tamalous Plain really affects how groundwater is recharged how minerals are deposited and what the water is like in terms of its chemistry.
In the few years the watershed has been under a lot of pressure from farming, urban development and wastewater. These activities can change the chemical properties of the water, which can affect whether it is safe to drink or use for farming. So it is really important to keep monitoring the water to manage it better and to support farming in the region.
To study the water we set up a network of eleven sampling stations. We had eight stations along the Guebli River where we sampled surface water and three stations in the aquifer where we sampled groundwater. We took samples every year from 2023 to 2025 to see how the water quality changed over time and from place, to place. We can see where the sampling stations are located in Figure 1 and their exact coordinates are listed in Table 1.

Table 1. coordinates of the sampling

Station	Water type	Latitude n	Longitude e
S1	Surface water	36.70	7.60
S2	Surface water	36.78	7.70
S3	Surface water	36.82	7.75
S4	Surface water	36.86	7.80
S5	Surface water	36.88	7.84
S6	Surface water	36.89	7.87
S7	Surface water	36.92	7.91
S8	Surface water	36.93	7.95
GW1	groundwater	36.71	7.61
GW2	groundwater	36.75	7.67
GW1	groundwater	36.77	7.72

Fig1. Site of study area and distribution of surface-water and groundwater sampling stations in Tamalous Plain, Algeria.

2.2 Sampling Strategy

We took water samples from eleven places along the Guebli River and the Tamalous Plain. There were eight spots on the river called S1 to S8 and three underground spots, called GW1 to GW3. We wanted to get an idea of what the water is like in these areas.

The water samples were collected over three years from 2023 to 2025. We took the surface water samples directly from the Guebli River. The underground water samples were taken from wells that tap into the water underground. Before we took the samples we made sure the wells were clean.

We put the water samples in bottles and kept them cool around 4 °C until we could take them to the laboratory for testing. We wanted to see what was in the water like how warm or cold it was and what kinds of things were in it.

2.3 Physicochemical and Trace Metal Analyses

We tested the water to see what was in it. We looked at things like the temperature, how acidic or basic it was and what kinds of salts were in it. We also looked for metals like iron and lead.

We used procedures in the laboratory to make sure our results were accurate. We wanted to know what the water was like so we could tell if it was good for drinking or for watering plants.

2.4 Hydrochemical Facies Analysis

We used a graph to understand what was in the water. We looked at the things and the bad things in the water like calcium and sodium and we looked at the percentages of each.

We plotted these percentages on a graph. Used it to figure out what kind of water we had. This helped us understand the water quality of the Guebli River and the Tamalous Plain.

2.5 Water quality assessment

2.5.1 Water Quality Index (WQI)

We used a number, called the Water Quality Index to rate the quality of the water. This number is like a report card for the water.

We looked at ten things in the water like how acidic it was and what kinds of salts were in it. We used all things to calculate the Water Quality parameter

We chose these things because they tell us a lot about the water and what it is like. The Water Quality Index helps us compare the water from places and see which water is better.

The quality rating, for each thing was calculated using an equation

To figure out the Water Quality Index we need to do some math.

First we calculate Qi which's the difference between the measured concentration of the parameter lets call it Vi and the ideal value, which is Vo divided by the standard permissible value, which is Si minus the ideal value Vo then multiplied by 100.

So it looks like this: Qi = Vi. Vo / Si. Vo * 100

Now lets break it down:

* Vi is the concentration of the parameter like how much of something is in the water.
* Si is the permissible value, which is the allowed amount of something in the water.
* Vo is the value, which is 0 for most things but for pH it is 7.0.

The relative weight, which we will call Wi for each parameter is determined by a formula: Wi = K / Si

Here K is a constant that we calculate using this formula: K = 1 / the sum of (1 / Si)

Then we use these weights to calculate the Water Quality Index, which is WQI = the sum of (Qi * Wi) / the sum of Wi

We use the standard values from the World Health Organization and the ideal values and the relative weights for the parameters we are looking at which are all in Table 2.

And to understand what the Water Quality Index means we use the classification in Table 3.

The Water Quality Index is calculated using the weighted method and the World Health Organization standard values are used for the selected parameters, like the Water Quality Index parameters.

The Water Quality Index values are then interpreted using the classification, which helps us understand the Water Quality Index

Table 2 WHO standard values, ideal values and relative weights used for Water Quality Index (WQI) calculation

Parameter	Unit	Standdart value Si	Ideal value Vo	Relative weight Wi
PH	µS/cm	8.6	7.0	0.4335
Electric conductivity	mg/L	1500	0	0.00246
Calcium Ca++	mg/L	76	0	0.04913
Magnisium Mg++	mg/L	50	0	0.07370
SodiumNa++	mg/L	200	0	0.01843
Potassium K+	Mg/L	12	0	0.30708
Chloride CL^-	Mg/L	250	0	0.01474
SulfateSO_4	Mg/L	250	0	0.01474
BicarbonateHCO_3	Mg/L	301	0	0.01228
Nitrate NO_{3-}	Mg/L	51		0.07370

Table 3. Classification of Water Quality Index (WQI) values according to Brown et al. (1972)

WQI	WATER QUALITY
0-25	Excelent
25-50	Good
51-75	Poor
76-100	Very poor
Plus100	Unsuitable for drinking

2.5.2 Irrigation Water Quality Assessment

In addition to the evaluation of drinking water quality, the suitability of surface water and groundwater for irrigation was assessed using two complementary hydrochemical indices: the Sodium Adsorption Ratio (SAR) and the Sodium Percentage (Na%). These indices were selected because they provide valuable information on the sodium hazard associated with irrigation water and its potential effects on soil permeability, structure and long-term agricultural productivity.

The Sodium Adsorption Ratio (SAR) was calculated using the following equation:

SAR=(Na^+)⁄√(Ca^(+2))+Mg^(+2)/2

where the concentrations of Na^+, Ca^{2+} and Mg^{2+} are expressed in milliequivalents per litre (meq/L).

The Sodium Percentage (Na%) was determined according to the following relationship:

Na%=((Na^++K^+)⁄ Ca^(+2)+Mg^(+2)+Na^++K^+)×100

where all ionic concentrations are expressed in milliequivalents per litre (meq/L). The calculated SAR and Na% values were interpreted according to the standard classification systems commonly used for assessing irrigation water quality.

Table 4. Classification of irrigation water according to the Sodium Adsorption Ratio (SAR).

SAR	Irrigation suitability
<10	Excellent
10–18	Good
18–26	Doubtful
>26	Unsuitable

Table 5. irrigation water according with Na Percentage (Na%).

Na (%)	Water quality
<20	Excellent
20–40	Good
40–60	Permissible
60–80	Doubtful
>80	Unsuitable

2.6 Analysis

The data that was gathered was used to look at how the physical and chemical features of surface water and groundwater changed over space and time during the study period. Basic statistics like the value, highest value, average and standard deviation were found for each variable that was looked at. Then Principal Component Analysis (PCA) was used to find the connections between the variables and to find the main things that influenced the changes in the water chemistry.

3. Discussion

3.1. chemical proprities of surface water and groundwater

The water chemistry of surface water and groundwater was studied to find the patterns that happened in space and time during the study period. The discussion talks about how the measured physical and chemical factors changed and about checking the quality of water for drinking and, for farming based on the numbers that were calculated.

Table 6 : Summary statistics of surface water chemical parameters (2023–2025).

Parameter	Unit	2023	2024	2025	Overall range	General trend
Temperature	°C	15–31	16–31	16–32	15–32	Slight increase
pH	–	7.0–7.8	7.1–7.9	7.2–8.0	7.0–8.0	Stable
EC	µS/cm	950–3900	1000–4200	1100–4500	950–4500	Increasing
Ca^{2+}	mg/L	52–125	55–130	60–135	52–135	Increasing
Mg^{2+}	mg/L	20–82	22–85	25–90	20–90	Increasing
Na^+	mg/L	65–290	70–300	75–310	65–310	Increasing
K^+	mg/L	2.8–10.1	3.0–10.5	3.2–11.0	2.8–11.0	Increasing
Cl^-	mg/L	85–360	90–370	95–380	85–380	Increasing
SO_4^{2-}	mg/L	65–305	70–315	75–330	65–330	Increasing

HCO_3^-	mg/L	170–325	175–330	180–340	170–340	Slight increase
BOD_5	mg/L	10–35	11–36	12–38	10–38	Increasing
NO_2^-	mg/L	0.05–20.0	0.06–21.0	0.07–22.0	0.05–22.0	Increasing
NO_3^-	mg/L	45–140	48–145	50–158	45–158	Increasing
Fe	mg/L	0.40–4.10	0.50–4.30	0.60–4.50	0.40–4.50	Increasing
Pb	mg/L	0.005–0.020	0.006–0.022	0.007–0.025	0.005–0.025	Slight increase

Surface water changed a lot over the 2023 to 2025 time when it was watched. The water got a warmer. The pH stayed about the same. This means the water was mostly neutral or a little bit alkaline. On the hand the electrical conductivity and most of the main ions went up over the time the study was happening. This shows that there were minerals dissolved in the water. The same patterns were seen for BOD_5, nitrite, nitrate and iron. This suggests that natural weathering and some human activities were becoming more important. Together the findings show that the surface water got more minerals over time. The physical and chemical conditions stayed mostly the same.

Table 7. Spatial and temporal variation of the physicochemical characteristics of groundwater during the study period (2023–2025).

Parameter	Unit	2023	2024	2025	Overall range	General trend
Temperature	°C	18–24	18–25	19–26	18–26	Slight increase
pH	–	7.1–7.3	7.2–7.4	7.3–7.6	7.1–7.6	Stable
EC	µS/cm	1000–1800	1100–2100	1200–2300	1000–2300	Increasing
Ca^{2+}	mg/L	55–80	60–90	65–95	55–95	Increasing
Mg^{2+}	mg/L	22–40	25–48	28–55	22–55	Increasing
Na^+	mg/L	65–120	75–140	80–170	65–170	Increasing
K^+	mg/L	2.5–4.5	2.8–5.2	3.0–6.0	2.5–6.0	Increasing
Cl^-	mg/L	85–150	95–180	100–220	85–220	Increasing
SO_4^{2-}	mg/L	70–130	80–150	85–180	70–180	Increasing
HCO_3^-	mg/L	165–220	170–230	175–250	165–250	Slight increase
BOD_5	mg/L	2.0–4.0	2.5–5.0	3.0–6.0	2.0–6.0	Increasing
NO_2^-	mg/L	0.01–0.03	0.02–0.04	0.03–0.05	0.01–0.05	Increasing
NO_3^-	mg/L	30–55	35–65	40–80	30–80	Increasing
Fe	mg/L	0.30–0.90	0.40–1.00	0.50–1.20	0.30–1.20	Increasing
Pb	mg/L	0.010–0.020	0.012–0.022	0.013–0.025	0.010–0.025	Slight increase

Groundwater showed relatively limited temporal variations compared with surface water during the 2023–2025 monitoring period. Temperature increased slightly, while pH remained stable, reflecting generally neutral hydrochemical conditions. Most physicochemical parameters, including electrical conductivity and the major ions, displayed a gradual increase over the study period, indicating progressive mineral enrichment of groundwater. Likewise, BOD_5, nitrite, nitrate and iron exhibited moderate upward trends, suggesting a slight increase in dissolved constituents without marked changes in the overall hydrochemical composition. Overall, groundwater quality remained relatively stable, although a gradual increase in mineralization was observed throughout the monitoring period.

3.2 Hydrochemical facies

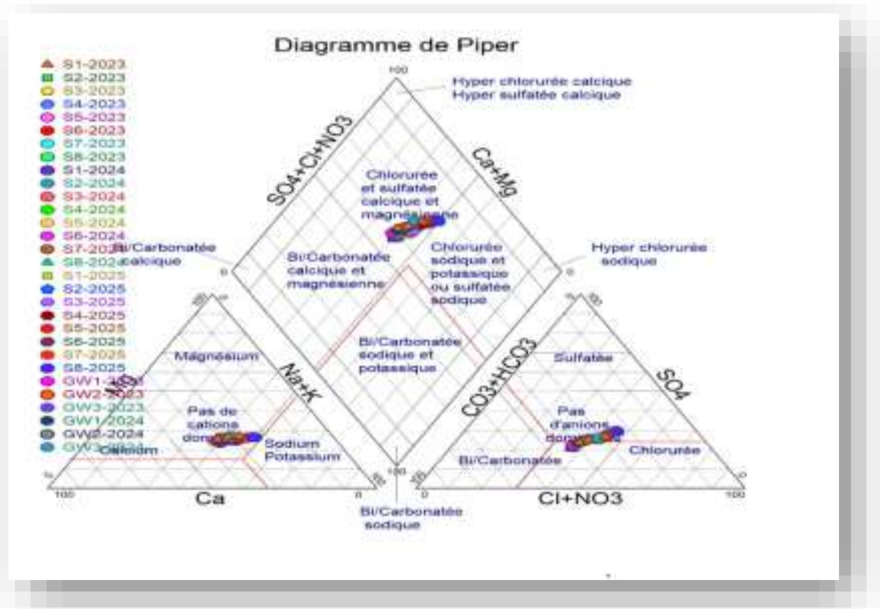

Figure 2. Piper diagram of surface water and groundwater in the Tamalous Plain

The Piper diagram shows that the investigated waters are mainly characterized by Ca^{2+} and Mg^{2+} among the major cations, while Cl^{-}, SO_4^{2-} and HCO_3^{-} represent the main anionic components. Most of the samples are distributed within mixed hydrochemical fields, with a predominance of calcium–magnesium and chloride–sulfate characteristics. This distribution indicates that the water chemistry is mainly influenced by dissolved major ions. Surface-water samples show a wider distribution, whereas groundwater samples are more closely grouped, indicating greater variability in surface-water chemistry.

3.3 All Principal Component Analysis (PCA)

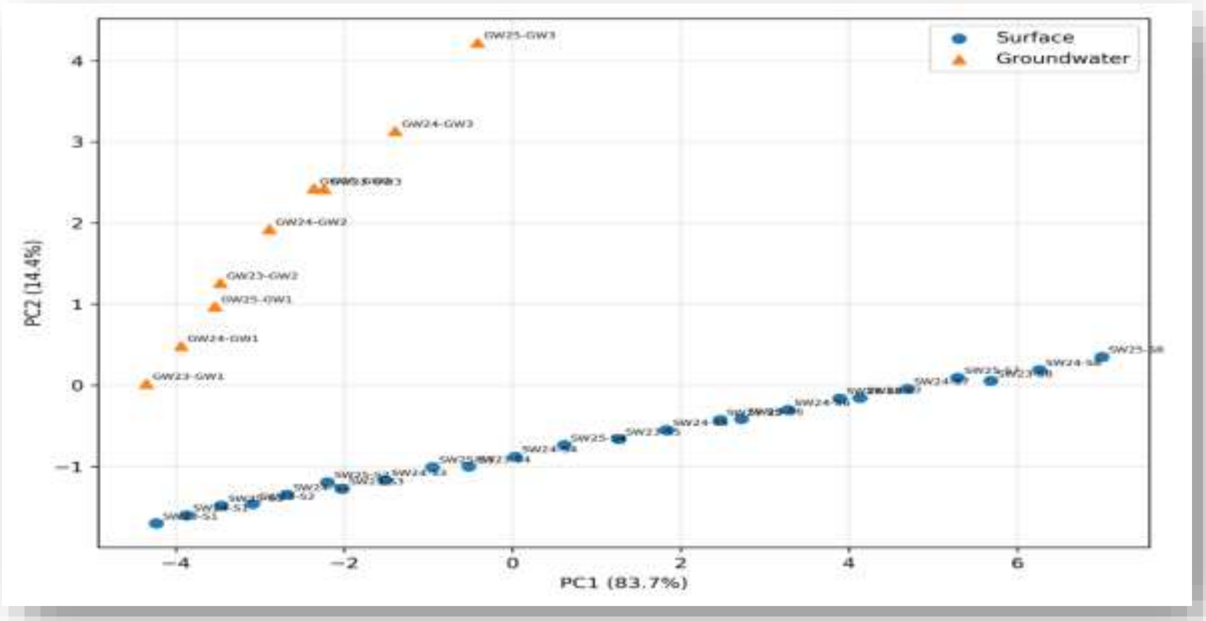

Figure 3. Principal Component Analysis (PCA) of surface water and groundwater samples based on the investigated physicochemical parameters.

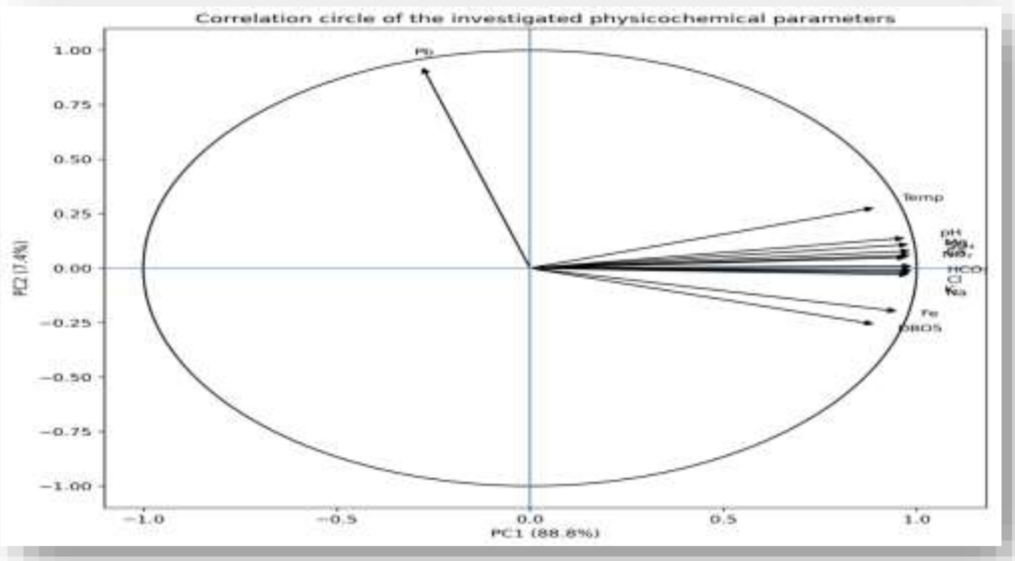

Figure 4. Correlation circle of the investigated physicochemical parameters

Figures 3 and 4 give us information about the hydrochemical proprities of water we looked at. The PCA biplot clearly separates the surface water and groundwater samples. The surface water samples are over the place but the groundwater samples are closer together. This means that the surface water chemistry is more varied.

The correlation circle shows that electrical conductivity is closely related to the ions like Calcium and Magnesium and Sodium and Potassium and Chloride and Sulfate and Bicarbonate and this relationship is mainly seen in the first principal component. This relationship tells us that the minerals and ions in the water are important for the water chemistry we see. Lead is different it is mainly related to the principal component, which means it behaves differently than the other ions. The water chemistry is controlled by the minerals and ions in the water and Figures 3. 4 Show us this information, about the hydrochemical characteristics of the investigated water

3.4. Water quality assessment

3.4.1. Drinking water quality (WQI)

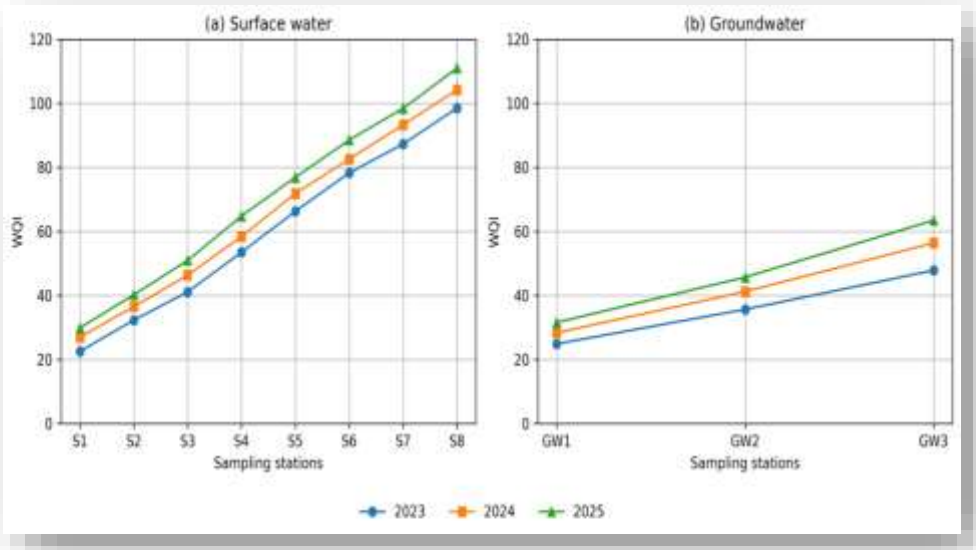

Figure 5. Spatial and temporal variation of the Water Quality Index (WQI) in surface water and groundwater during the 2023–2025 monitoring period.

Table 8. Water Quality Index (WQI) values and corresponding water quality classes for surface water and groundwater during the 2023–2025 monitoring period.

Year	Water type	Station	WQI	Water quality
2023	Surface water	S1	22.49	Excellent
2023	Surface water	S2	32.25	Good
2023	Surface water	S3	41.07	Good
2023	Surface water	S4	53.45	Poor
2023	Surface water	S5	66.24	Poor
2023	Surface water	S6	78.26	Very Poor
2023	Surface water	S7	87.24	Very Poor
2023	Surface water	S8	98.44	Very Poor
2023	Groundwater	GW1	24.84	Excellent
2023	Groundwater	GW2	35.62	Good
2023	Groundwater	GW3	47.81	Good
2024	Surface water	S1	26.96	Good
2024	Surface water	S2	36.46	Good
2024	Surface water	S3	46.29	Good
2024	Surface water	S4	58.34	Poor
2024	Surface water	S5	71.81	Poor
2024	Surface water	S6	82.54	Very Poor
2024	Surface water	S7	93.26	Very Poor
2024	Surface water	S8	104.14	Unsuitable for drinking
2024	Groundwater	GW1	28.31	Good
2024	Groundwater	GW2	41.18	Good
2024	Groundwater	GW3	56.37	Poor
2025	Surface water	S1	29.83	Good
2025	Surface water	S2	40.17	Good
2025	Surface water	S3	50.92	Poor
2025	Surface water	S4	64.76	Poor
2025	Surface water	S5	76.84	Very Poor
2025	Surface water	S6	88.51	Very Poor
2025	Surface water	S7	98.37	Very Poor
2025	Surface water	S8	110.92	Unsuitable for drinking
2025	Groundwater	GW1	31.54	Good
2025	Groundwater	GW2	45.67	Good
2025	Groundwater	GW3	63.42	Poor

the results shown in Figure 5 and Table 8 show a rise in WQI values for both surface water and groundwater during the 2023–2025 monitoring period. Surface water had differences in space than groundwater with the highest WQI values always found at the downstream stations. According to the WQI classification surface water was Excellent at the stations but became Very Poor or in some cases not safe for drinking at the downstream areas. Groundwater had WQI values and stayed in the Excellent, Good or Poor categories all through the study period, which means better overall water quality. These results show that water quality got worse, from upstream to downstream and prove that groundwater was not as affected as surface water under the conditions seen during the monitoring period.

3.4.2. Irrigation water quality

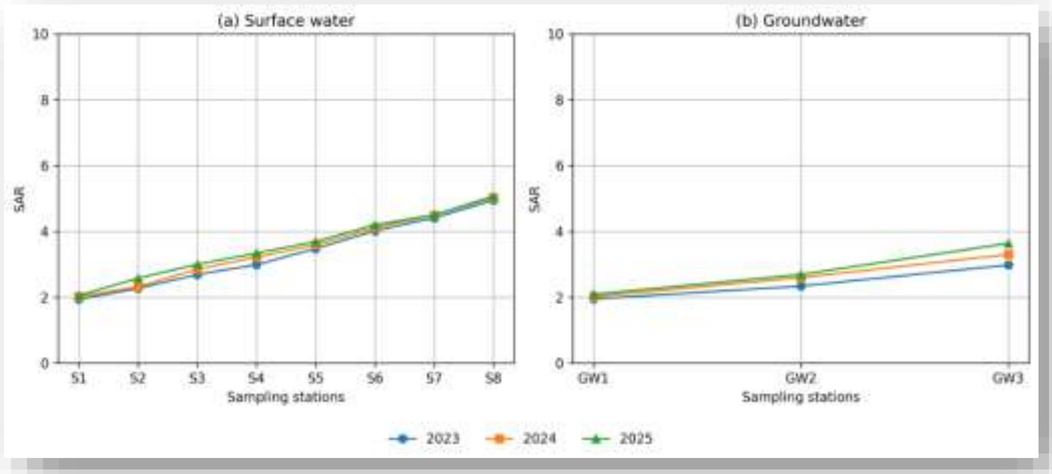

Figure 6. Spatial and temporal variation of the Sodium Adsorption Ratio (SAR) in surface water and groundwater during the 2023–2025 monitoring period.

Figure 6 shows that the SAR values for surface water and groundwater went up a little from 2023 to 2025. The surface water had a lot of variation in areas. The highest SAR values for surface water were found at the stations that were downstream. On the hand the groundwater had lower SAR values that were pretty much the same everywhere. Even though the SAR values are going up they stayed pretty low for both types of water. This means that there is not a risk of sodium being a problem for irrigation during the time we were studying the SAR values, for surface water and groundwater.

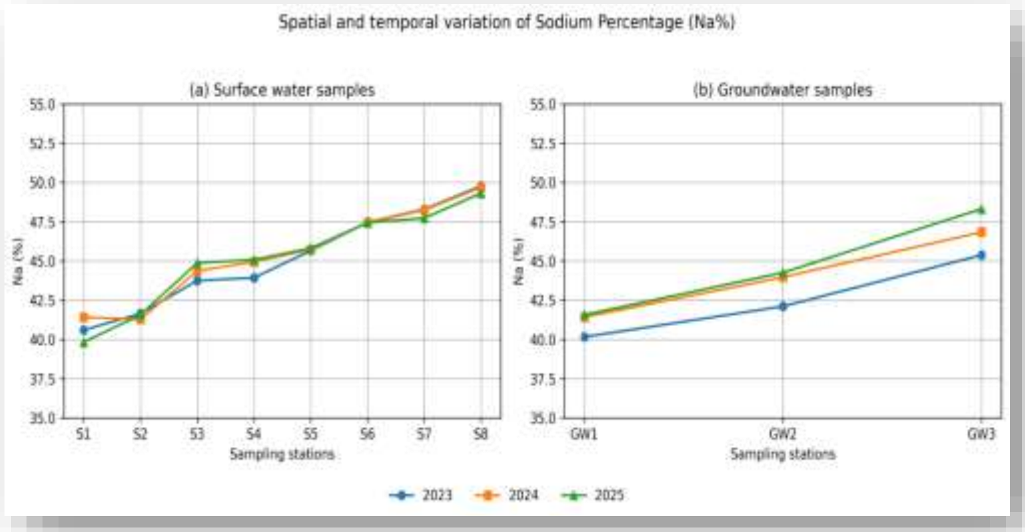

Figure 7. How the percentage of sodium in surface water and groundwater changes over space and time during the monitoring period from 2023, to 2025

Figure 7 shows a gradual increase in Na% from upstream to downstream stations in both surface water and groundwater throughout the 2023–2025 monitoring period. Surface water exhibited slightly higher spatial variability, whereas groundwater showed a more uniform distribution. Although Na% increased over time, all values remained below 60%, indicating that both water types are generally suitable for irrigation according to the Wilcox classification.

Overall, the hydrochemical indices indicate that groundwater exhibited better water quality than surface water throughout the study period. The progressive increase in WQI, SAR and Na% from upstream to downstream reflects a gradual increase in dissolved salts and sodium content. Nevertheless, the SAR and Na% values remained within the acceptable range for irrigation, indicating a low risk of soil sodicity. These results suggest that groundwater remains the more suitable resource for drinking purposes, whereas both surface water and groundwater can generally be used for irrigation under appropriate management practices.

4. Discussion

The Piper diagram showed that the investigated waters were mainly characterized by Ca^{2+} and Mg^{2+} among the major cations, with an important contribution of Cl^-, SO_4^{2-} and HCO_3^- among the anions. Most samples were distributed within mixed hydrochemical fields, indicating that no single ion completely controlled the water composition. The predominance of calcium and magnesium is consistent with the geological setting of the Tamalous Plain, where water–rock interactions can contribute to the dissolution of mineral constituents. The contribution of chloride and sulfate may also reflect the combined influence of natural mineral dissolution and human activities within the watershed.

The spatial evolution of electrical conductivity and major ions provides further evidence of increasing mineralization from upstream to downstream. Surface water showed a greater increase and wider spatial variability than groundwater, while groundwater remained more homogeneous. This difference may be related to the direct exposure of the river to surface inputs, runoff and human activities, whereas groundwater chemistry is also influenced by residence time and interaction with the alluvial aquifer. The observed increase in mineralization should therefore be considered as the result of both natural processes and possible anthropogenic inputs rather than being attributed to a single source.

The PCA results support the hydrochemical pattern identified by the Piper diagram. Electrical conductivity and the major ions were strongly associated, showing that dissolved ions and mineralization play an important role in controlling the observed water chemistry. The different distribution of Pb suggests that this element does not follow exactly the same pattern as the major dissolved ions. However, the PCA alone cannot identify the origin of the observed constituents. The combined interpretation with the spatial trends and hydrochemical characteristics suggests that natural water–rock interaction is an important control, while the contribution of agricultural, domestic and other human activities cannot be excluded, particularly in downstream areas.

The WQI results are consistent with the observed hydrochemical changes. The progressive increase in WQI values from upstream to downstream, particularly in surface water, indicates a gradual deterioration in overall water quality. The higher WQI values observed at

The water quality in stations is getting worse because of the increase in electrical conductivity and major ion concentrations. This means that the dissolved constituents are in the water the worse the water quality becomes. However the Water Quality Index or WQI for short only gives us an idea of the water quality and does not tell us what is causing the problem.

The irrigation indices give us a view of the water quality. Even though the Sodium Adsorption Ratio or SAR and the percentage of sodium or Na% increased from the stations to the downstream stations they are still within the acceptable limits for irrigation. This shows that the increase in salts and sodium is not a major problem for irrigation right now. So the deterioration of water quality that the WQI shows does not necessarily mean that there is a risk of sodicity.

The groundwater has overall quality and more stable hydrochemical conditions than the surface water with lower WQI values and less variation in SAR and Na%.

Overall the results from the Piper diagram, Principal Component Analysis or PCA WQI, SAR and Na% all provide information about the water resources of the Tamalous Plain. The Piper diagram tells us about the hydrochemical characteristics of the water while the PCA highlights the importance of mineralization and dissolved ions. The WQI shows that the water quality is getting worse in the downstream surface-water stations. Meanwhile the SAR and Na% show that the risk of sodium hazard, for irrigation is still limited. All these results together suggest that the water is becoming more mineralized as it moves along the plain, which is controlled by hydrochemical processes and may be made worse by human activities. To addition is important to take monitoring the water quality in the downstream areas where the changes are more noticeable.

5. Conclusion

The study looked at the water quality of surface water and groundwater in the Tamalous Plain from 2023 to 2025. The results showed that the water is getting more mineralized which means it has salts and other things in it. This is because the electrical conductivity is going up and there are big ions in the water.. The pH level is staying about the same.

When we looked at the Piper diagram we saw that the water has a lot of calcium and magnesium in it and also some chloride, sulfate and bicarbonate. This means that the water has a chemistry.

The PCA results were similar to what we saw in the pattern. They showed that the mineralization and the big ions in the water are very important for the water chemistry. The surface water is more different from one place to another than the groundwater in the areas downstream. We saw that the water quality is getting worse in these areas.

The WQI results showed that the surface water quality is getting worse as you move downstream. The groundwater is still pretty good. Even though the SAR and Na% values are going up a bit over time and downstream they are still okay for irrigation. This means that the water is not too salty for farming.

All the results, including the Piper diagram, PCA, WQI, SAR and Na% give us a picture of what is happening to the water in the Tamalous Plain. The changes we see are probably because of things like the water interacting with the rocks and also maybe because of things that people are doing in the downstream areas.
Overall the groundwater seems to be better and more stable, than the surface water.. We need to pay special attention to the downstream part of the Guebli River because the water quality is getting worse there. If we keep monitoring the water and take samples at times of the year we can better understand what is happening to the water and make sure we are using the water resources of the Tamalous Plain in a sustainable way. The Tamalous Plain water resources need to be managed so we should continue to monitor the Tamalous Plain water.

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Voici une version reformulée du texte :

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