The Effect of Climate and Continental Hydrological Factors on the Salinity of Seawater of Latakia Coast

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□ ABSTRACT □

The research aims to analyze the change in seawater salinity along the Latakia coast in relation to the influence of the two most significant climate elements: precipitation and evaporation. It also considers continental hydrological factors, represented by the flow of the Al Kabeer Alshemaly River, as well as sewage contributions from the Afamia and Al Corniche aljanuby estuaries. The study relied on field research, which involved collecting samples and measuring parameters directly at the sampling locations, followed by data analysis to derive a set of result.

The concepts of surface water mass and seawater salinity were defined, along with the average seawater salinity in the research area, which represents the typical salinity of the surface water mass in Syrian territorial waters, as indicated by the station of the Higher Institute of Marine Research, a typical station distant from human influences. The variation in seawater salinity was analyzed based on the months of the year 2023. The extent of the impact of seawater salinity on the Latakia coast was assessed in relation to climatic elements and the river flow of the Al Kabeer Alshemaly River, considering different distances from the estuary, as well as the influence of human factors.

Keywords: Seawater Salinity, hydrological factors, Al Kabeer Alshemaly River.

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تأثير المناخ والعوامل الهيدرولوجية القارية على ملوحة مياه البحر في ساحل اللاذقية

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□ ملخّص □

يهدف البحث إلى تحليل تغير ملوحة مياه البحر على طول ساحل اللاذقية وفقاً لتأثير الهطل والتبخر باعتبارهما أهم عُنصرين مُناخيين. كما يأخذ البحث في الاعتبار العوامل الهيدرولوجية القارية، والمتمثلة بتدفق نهر الكبير الشمالي، بالإضافة إلى المساهمة الناتجة عن مياه الصرف الصحي من مصبي أفاميا والكورنيش الجنوبي. اعتمدت الدراسة على البحث الميداني، حيث تم جمع العينات وقياس المؤشرات مباشرة في مواقع السحب، تلا ذلك تحليل البيانات للوصول إلى مجموعة من النتائج. تم تحديد مفهومي كتلة المياه السطحية وملوحة مياه البحر، إلى جانب تحديد متوسط ملوحة مياه البحر في منطقة البحث، والذي يمثل الملوحة النموذجية للكتلة المائية السطحية في المياه الإقليمية السورية، كما هو موضح في محطة المعهد العالي للبحوث البحرية، وهي محطة نموذجية بعيدة عن التأثيرات البشرية. تم تحليل تباين ملوحة مياه البحر بالاعتماد على أشهر عام 2023. كما تم تقييم مدى تأثير ملوحة مياه البحر على ساحل اللاذقية فيما يتعلق بالعناصر المناخية وتدفق نهر الكبير الشمالي، مع الأخذ بعين الاعتبار المسافات المختلفة عن المصب، بالإضافة إلى تأثير العوامل البشرية.

الكلمات المفتاحية: ملوحة مياه البحر، العوامل الهيدرولوجية، النهر الكبير الشمالي.

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Introduction:

The relationship between the amount of water gained (water intake) from all types of precipitation and the water that flows from rivers, as well as the amount of water lost (water loss) through evaporation and water exchange with neighboring seas and oceans, are the most significant factors influencing the salinity of sea and ocean waters. The distribution of salinity in surface waters is affected by the intensity of thermal climatic conditions, particularly humidity, as well as by the movement and continuity of winds, all of which influence the rate of evaporation. Additionally, it is also influenced, albeit to a lesser extent, by the fresh river water and various drainage waters that flow into seas and oceans.

Many local studies were conducted, such as Abdo [1] which studied the distribution of a group of heavy metal pollutants (Cu, Cr, Cd, Zn, Fe, Ni, Pb, & Mn) in the waters of the northern Kabir River estuary and its sediments; and the study of Zainab [2] which studied some physical, chemical, and biochemical measurements in addition to the count of heterotrophic bacteria, total coliforms T.C, fecal coliforms F.C, and enterococci F.S for two sites on the northern Kabir River and its estuary; and the study of Haloul [3] which studied a number of indicators of chemical pollution of marine waters in the commercial port area, in addition to studying fecal pollution microbes (total coliform T.C and fecal F.C), and fecal streptococci F.C.

The research problem lies in the increase in the salinity of coastal waters of Latakia Governorate due to the negative water balance and various human impacts, which negatively affects the marine environment of the research area.

The importance of the research can be summarized in:

1. Clarifying the extent to which coastal waters of Latakia Governorate are affected by various factors.
2. Analyzing the water balance in the Syrian coast and its impact on the increase in salinity.
3. Analyzing the impact of the marine environment on changes in the salinity of marine waters.

So the research aimed to:

1. Determine the typical salinity of the marine waters of Latakia Beach in comparison to global sea waters.
2. Clarify the impact of climatic factors on the salinity of the marine waters of Latakia Beach.
3. Clarify the influence of continental hydrological factors on the salinity of the marine waters of Latakia Beach.

Research Materials and Tools:

Methodology and material:

Research area:

Astronomical location: The research area extends between longitudes (35º 45' 00") and (35º 46' 30") east of Greenwich, and between latitudes (35º 29' 30") and (35º 36' 30") north of the equator figure (1).

Geographical location: The research area encompasses the location of the Higher Institute for Marine Research, the mouth of the Al Kabeer Alshemaly River, and the sewage outlets in Afamia and Al Corniche aljanuby, as shown in Table (1).

Table (1) Sample collection stations and their distance from the beach m.

Stations	distance from the beach m	Coordinates
Higher Institute for Marine Research	1000	N 35° 35.554' E 35° 43.948'
Al Kabeer Alshemaly River A	200	N 35° 29.882' E 35° 48.609'
Al Kabeer Alshemaly River B	500	N 35° 29.762' E 35° 48.479'
Al Kabeer Alshemaly River C	1000	N 35° 29.558' E 35° 48.254'
Afamia	200	N 35° 32.335' E 35° 45.659'
Al Corniche aljanuby	20	N 35° 30.091' E 35° 46.385'

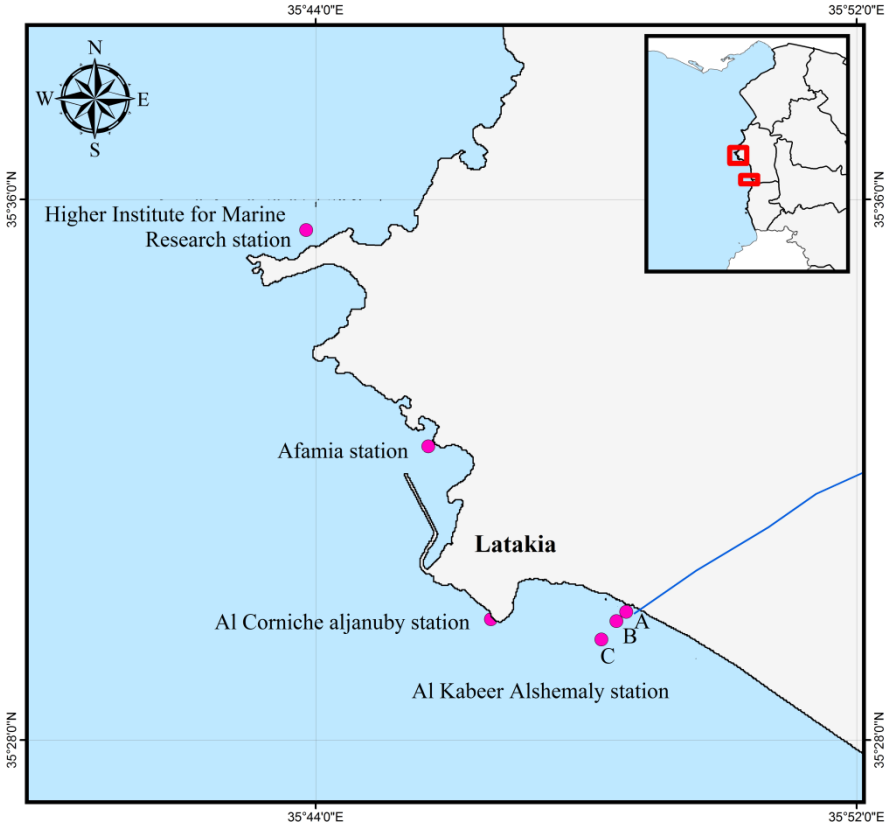

Figure (1) Marine water sample collection stations opposite the Latakia coast.

Research methodology:

1. Field Study and Sample Collection: Samples were collected after marine trips using a device for water sampling with a frequency of three samples. Water properties such as temperature, salinity, pH, and dissolved oxygen were measured directly at the sampling site. International quality control standards were adhered to by using sterile and appropriate containers, precise procedures for sample documentation, regular calibration of devices, and comprehensive documentation of all process steps to ensure the reliability of the results.
2. Quantitative analysis and conclusion: An inductive and deductive approach was employed to analyze data and information based on a robust scientific methodology, leading to the attainment of results. After collecting and analyzing the samples, a series of results were obtained. The dispersion coefficient and Pearson correlation coefficient were also employed to support the accuracy of the analysis and results.

Results and Discussion:

First: Salinity of the surface water of Latakia beach

1. Surface water mass (MAW)

The surface water mass in the Syrian territorial waters extends from the surface to a depth of (-90) m [4], and Figure (2) illustrates the distribution of the Atlantic surface water mass in the Syrian territorial waters off the coast of the city of Jableh as a selected model:

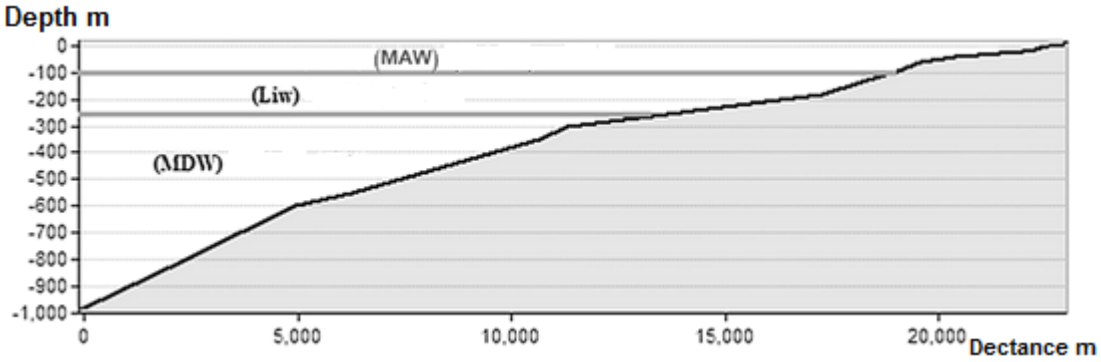

Figure (2) The extension of the surface water mass in the Syrian territorial waters off the coast of Jableh city.

The surface water mass of the Syrian territorial waters is divided into two main water masses: Levantine Surface Water (LSW) and Atlantic Surface Water (MAW).

The surface water mass (MAW) is the predominant water mass in the Syrian surface waters, consisting of Atlantic water that enters the Mediterranean Sea via the Atlantic Surface Water Current (MAW) through the Strait of Gibraltar [5]. On the other hand, the Levantine water mass is also Atlantic water, but it enters the Mediterranean Sea at low temperatures and low salinity (36‰). However, as it moves east from the Strait of Gibraltar, both temperature and salinity increase, reaching their peak values in the eastern basin. The water temperature in the Syrian territorial waters reached (32.4º) in July and (19º) in March [6].

The research samples are situated within the surface coastal waters (MAW), which have a thickness of no less than 15 meters in Syrian territorial waters. The horizontal distribution of the characteristics of these waters is marked by significant complexity, due to their direct relationship with climatic elements such as temperature, humidity, and winds, as well as continental hydrological factors represented by river water and sewage water flowing into the sea. Consequently, the characteristics of this water mass are not static; they vary seasonally and monthly. Thus, the characteristics of this mass were assessed across the different months of the year.

2. Average Salinity of Latakia Beach Marine Water

Salinity is a fundamental concept in oceanography, typically measured in parts per thousand (‰ or per mile). The open ocean has an average salinity of about 35 grams (1.2 ounces) of solids per liter, corresponding to a salinity of 35 ‰. In contrast, the Mediterranean Sea has a slightly higher salinity, reaching 38 ‰ [7] while the northern Red Sea can attain salinity levels of up to 41 ‰. Conversely, some non-coastal hypersaline lakes exhibit significantly higher salinity; for instance, the Dead Sea contains 300 grams (11 ounces) of dissolved solids per liter, equivalent to 300 ‰

Although the primary components of table salt (sodium and chloride) account for approximately 85% of the dissolved solids, other mineral ions such as magnesium and calcium, as well as negative ions like sulfates, carbonates, and bromide, are also present.

Despite the variations in salinity across different seas, the relative composition of dissolved salts remains consistent throughout the world's oceans [8].

Table (2) the main components of 1 kg of seawater at a salinity of 35‰

cationes	gram		%	aniones	gram		%
Sodium	**Na^+**	**10.75**	**30.6**	**Chlorine**	**Cl^-**	**19.35**	**55.3**
Magnesium	**Mg^{++}**	**1.3**	**3.7**	**Sulphate**	**SO_4^{--}**	**2.7**	**7.7**
Calcium	**Ca^{++}**	**0.42**	**1.2**	**Bicarbonate**	**NCO_3^-**	**0.14**	**0.4**
Potassium	**K^+**	**0.39**	**1.1**	**Bromine**	**Br^-**	**0.066**	**0.2**
Strontium	**Sr^{++}**	**0.01**	**0.04**	**Borate**	**BO_3^{---}**	**0.027**	**0.08**

Table (3) Salts obtained after evaporating 1 kg of seawater

Salts		gram	%
Sodium chloride	NaCl	27.213	77.758
Magnesium chloride	MgCl	1.3807	10.878
Magnesium sulphate	$MgSO_4$	1.658	4.737
Calcium sulphate	$CaSO_4$	1.26	3.600
Potassium sulphate	K_2SO_4	0.863	2.465
Calcium carbonate	$CaCO_2$	0.123	0.345
Magnesium bromide	$MgBr_2$	0.0766	0.217
		35.000	100.000

The salinity of the seawater at Latakia beach was assessed using samples from the station of the Higher Institute for Marine Research (Ras Ibn Hani Reserve). This model station is situated within the Ras Ibn Hani Reserve, which is directly exposed to the sea and relatively unaffected by human activities. The samples were collected from a distance of 1000 meters west of the Higher Institute for Marine Research - Blue Beach.

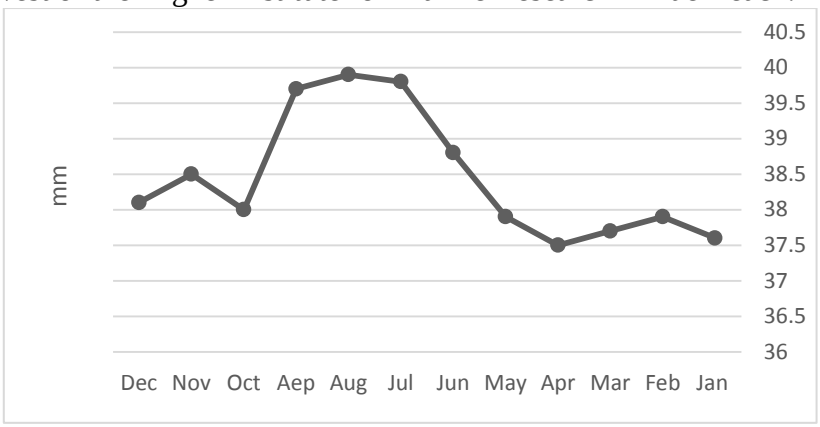

Figure (3) Average salinity of sea water on the Latakia coast.

The average salinity of the surface seawater at Latakia beach was 38.45 ‰. This percentage fluctuated throughout the various months of the year, influenced by different climatic factors such as precipitation, temperature, and evaporation, as it is directly exposed to the atmosphere. The salinity percentage in the Syrian surface water at the station of the Higher Institute for Marine Research ranged between (37.5 ‰) and (39.9 ‰).

Second: The impact of climate on the salinity of sea waters of Latakia coast

1. The impact of precipitation

It is evident from Figure (4) that the amount of precipitation over Syrian territorial waters varied between (0 mm) and (190 mm), with the highest precipitation levels occurring in December, attributed to the increasing intensity of the depressions originating from the west. Conversely, there was no precipitation in July and August due to the dominance of the Azores high pressure over the western part of the Mediterranean Sea, which obstructs the arrival of the westerly winds from the Atlantic Ocean, resulting in drought.

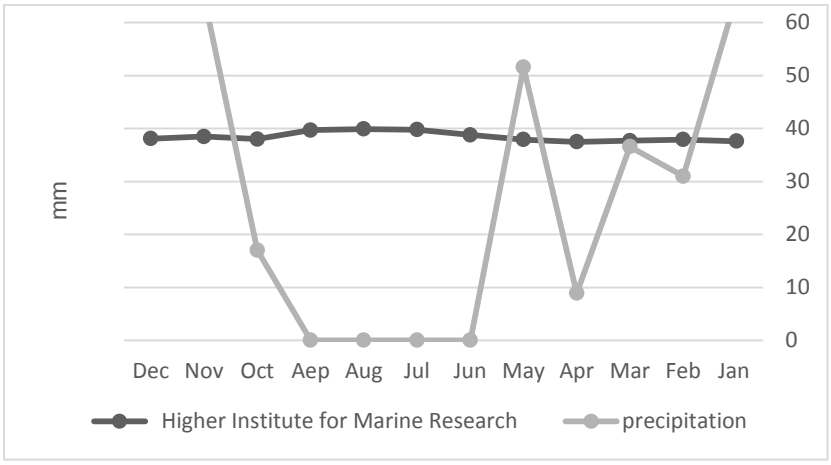

Figure (4) The inverse correlation between precipitation and salinity on the Latakia coast.

Figure (4) illustrates the inverse relationship between precipitation and seawater salinity along the Latakia coast. Increased precipitation in the sea and surrounding areas leads to greater dilution of salts, resulting in fresher water over time. The highest salinity was observed in the summer, peaking at (39.9‰) in August. This increase is attributed to significant evaporation and minimal precipitation in July and August. Conversely, the lowest salinity was noted in early spring, with values of (37.7‰) in March and (37.5‰) in April, due to reduced evaporation and substantial precipitation, which reached (190 mm) during the winter.

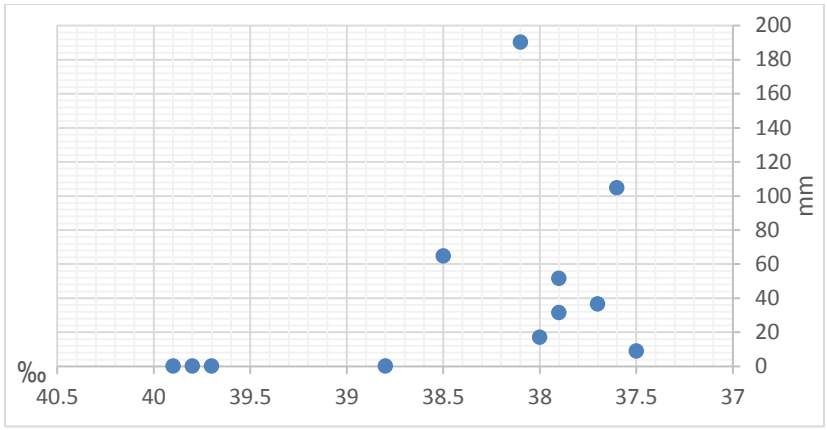

Figure (5) The correlation between salinity levels and precipitation rates.

The diffusion coefficient in the previous figure shows an inverse relationship between salinity levels and precipitation rates, as the points generally trend downward from left to right, indicating that salinity levels rise as precipitation rates fall. Furthermore, the Pearson correlation coefficient between salinity levels and precipitation rate was calculated to be (-0.43), which supports the inverse relationship between these two variables (Figure 5).

2. The effect of evaporation

Ivanov's relationship was utilized to calculate evaporation [9], based on the average temperature and relative humidity, establishing that evaporation has an inverse linear relationship with the degree of the air's proximity or distance from saturation with water vapor. The greater the relative humidity values in the atmosphere, the lower the evaporation rate.

$E = 0.0018\ (25+T)^2 \times (100-H)$
Where:
E = Monthly evaporation (mm)
T = Monthly average temperature (ºC)
H = Monthly average relative humidity (%)

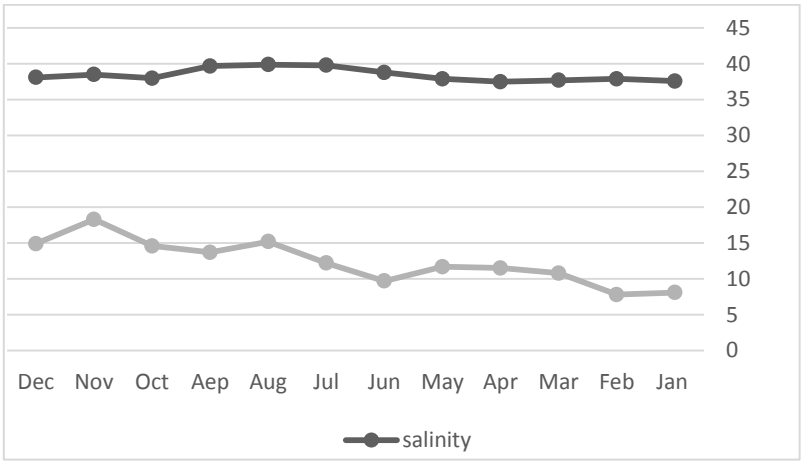

Figure (6) The direct correlation between evaporation and salinity on the Latakia coast.

Figure (6) illustrates the direct correlation between evaporation and salinity of seawater along the Latakia coast. As the salinity level increases in water bodies where evaporation rises, this indicates that the amount of water lost due to evaporation surpasses the water gained from precipitation. This direct relationship between salinity and evaporation persists during the winter, spring, and summer months, but shifts to an inverse relationship in the fall. During this season, salinity decreases while evaporation peaks due to increased wind speed.

The salinity levels in the Syrian surface waters at the Higher Institute for Marine Research station ranged from (37.5 ‰) to (39.9 ‰). The highest salinity was recorded in the summer, reaching (39.9 ‰) in August, attributed to a significant evaporation rate of (152.6 mm) and minimal rainfall in July and August. Conversely, the lowest salinity was observed in winter and early spring, with values of (37.7 ‰) in March and (37.5 ‰) in April, due to reduced evaporation, which did not exceed (77.9 mm) in February, alongside increased rainfall totaling (190 mm) in that same month.

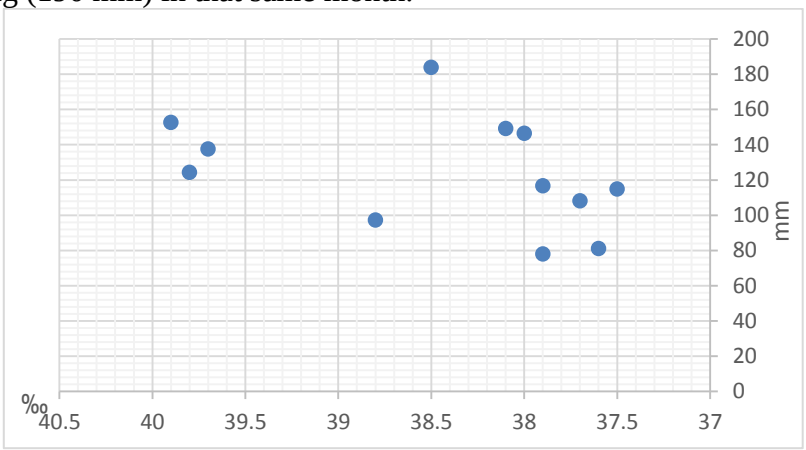

Figure (7) The correlation between salinity levels and evaporation rates.

The spread factor in the figure (7) indicates a positive correlation between salinity levels and evaporation rates, as the points generally trend upwards from left to right, suggesting that salinity increases with higher evaporation rates. The Pearson correlation coefficient value between salinity percentage and evaporation rate was (0.39), confirming the direct correlation between salinity percentage and evaporation rate.

Second: The effect of continental hydrological factors on the salinity of seawater on the Latakia coast

1. The effect of river flow

River flow helps to reduce the salinity of seawater because freshwater inputs dilute the salts present in seawater, thereby lowering its concentration. The salinity levels at the Al Kabeer Alshemaly station varied between (19.1 ‰) and (38.9 ‰), as illustrated in Figure (8). The lowest salinity level recorded during the year was (19.1 ‰) at the (Al Kabeer Alshemaly A) station in January. Following this, salinity values gradually increased as one moves towards the seawater, reaching (38.9 ‰) at the (Al Kabeer Alshemaly B) station in November. A salinity gradient was observed in the months of December, January, February, and March, characterized by increased river flow. This gradient exceeded (1000 m) at the (Al Kabeer Alshemaly C) station, attributed to the decrease in salinity during the winter months due to significant precipitation (190 mm) in December, along with the river flows entering the sea via the drainage funnel of the (16) Tishreen Dam Lake, which can discharge (30) m^3/s when water levels surpass the dam's storage capacity due to rainfall in wet years. Conversely, river flow diminishes and evaporation increases during the summer, reaching (152.6 mm) in August, as temperatures rise to (30.6) °C, resulting in an increase in salinity levels.

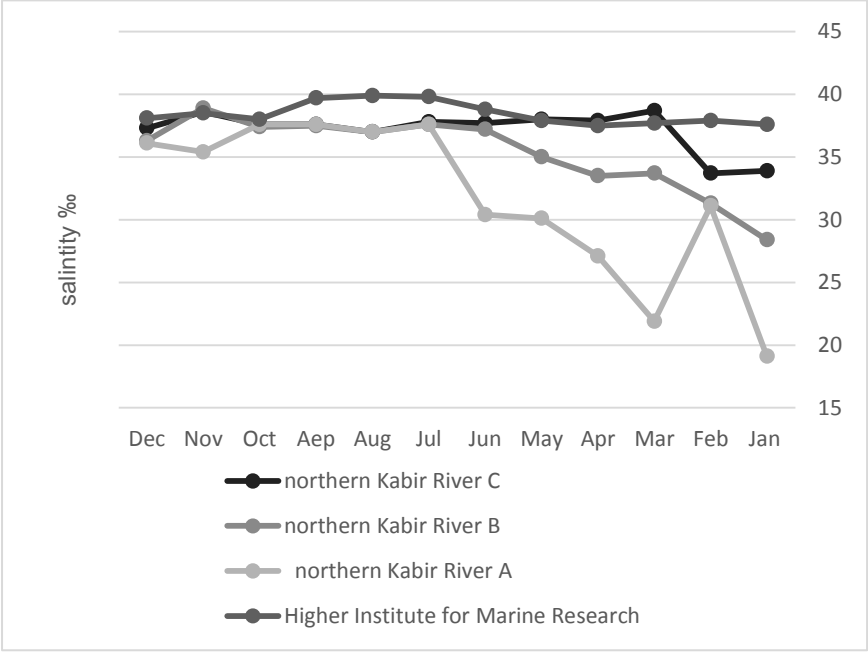

Figure (8) Distribution of salinity (‰) in the stations of Al Kabeer Alshemaly River estuary

2. Impact of sewage flow

The city of Latakia manages its sewage waste by collecting it in an extensive network of sewage channels that operate with a mixed drainage system (domestic, industrial, and rainwater), which flows into the sea through thirteen sewage outlets [10]. The most significant of these is the Afamia outlet located north of the city, along with other

important outlets such as the Al Corniche aljanuby outlet and the port outlet. Latakia lacks a sewage treatment plant, resulting in all sewage flowing directly onto the beach.

- Afamia Outfall: The largest volume of sewage water from Latakia city is discharged at the Afamia site, as illustrated in figure (9). This outfall releases domestic and industrial sewage water from most of the old city, which has the highest population density. It also discharges sewage water from the site of the tenth project, home to approximately 18,000 residents. In total, it disposes of waste from about 400,000 people, accounting for most of the sewage water from Latakia city, which has a population of around 470,354 people [11].

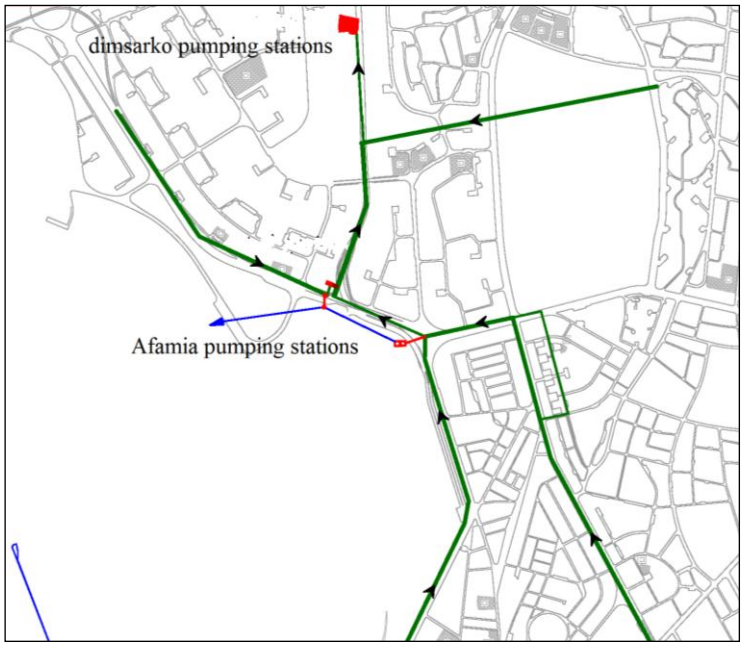

Figure (9) The sewage lines that flow into the Afamia site, and the pumping stations that will be activated

- Al Corniche aljanuby Outfall: The sewage in the Al Corniche aljanuby area flows directly into the sea without any prior treatment. Furthermore, there is no separation between domestic wastewater, rainwater drainage, and industrial effluents [12]. This situation has complicated the sewage treatment process, as approximately 141,000 m^3 of domestic wastewater is discharged daily into the Latakia Governorate shore through sewage outfalls, the most significant of which are Afamia and Al Corniche aljanuby, with about 99% of it being untreated. The volume of sewage outflow in the Al Corniche aljanuby is estimated at approximately 700 liters per second, equivalent to 3,600,000 liters per day. It discharges both domestic and industrial wastewater from small workshops and shops in various areas of the city of Latakia, particularly from the Saliba area and the entire head of the Al Corniche aljanuby, affecting the waste of approximately 101,944 people [10].

To mitigate the pollution of marine waters caused by mixed sewage (sanitary and industrial) in the Al Corniche aljanuby area, the relevant authorities are planning a project to establish 13 pumping and lifting stations along the entire Syrian coast, including a pumping station in the Al Corniche aljanuby area, as depicted in Figure (10). The sewage will then be pumped to a main pumping station (Damsarkho) and subsequently to the treatment plant, as illustrated in Figure (11).

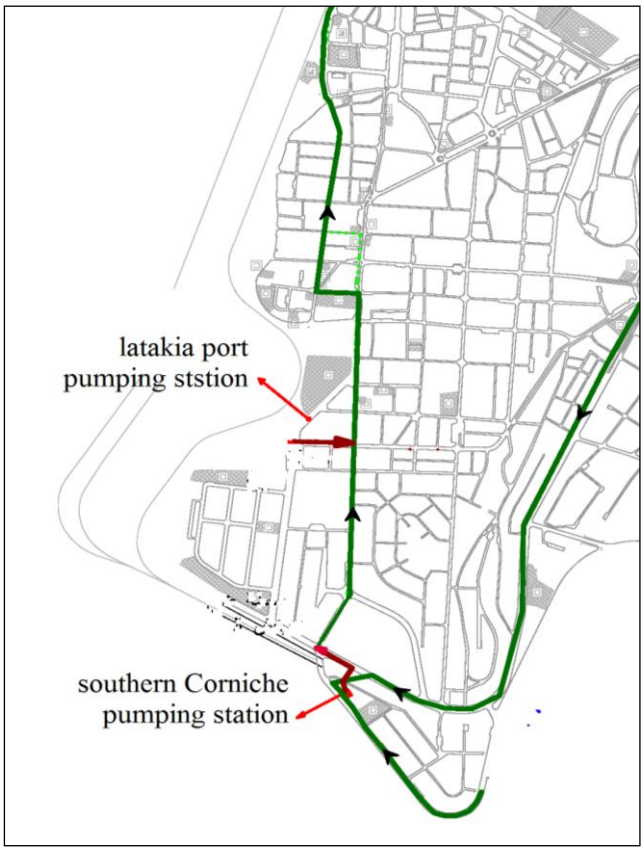

Figure (10) The sewage network and pumping station of the southern Corniche

The salinity of seawater at the Afamia station ranged from (35.8‰) to (38.5‰), with the maximum salinity of (38.5‰) recorded in November during the fall, and the minimum salinity of (35.8‰) recorded in January during the winter. Meanwhile, the salinity of seawater at the Al Corniche aljanuby station varied between (37.9‰) and (35.6‰), with the highest salinity of (37.9‰) observed in December during the winter, and the lowest salinity of (35.6‰) noted in May during the spring.

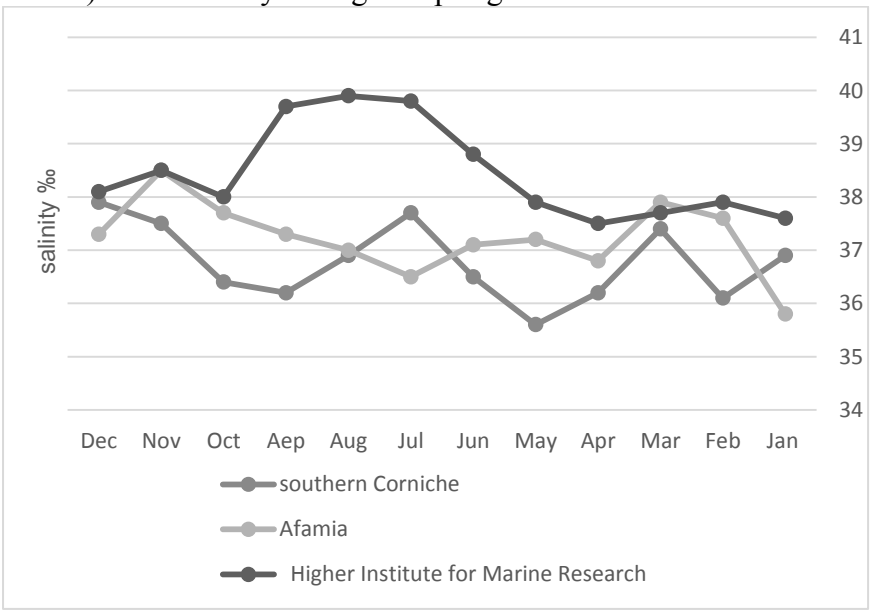

Figure (11) Distribution of salinity (‰) in Afamia station and Al Corniche aljanuby stations

It is evident from the comparison of salinity ratios throughout the year between the Higher Institute of Marine Research station as a baseline and the Afamia and Al Corniche aljanuby stations, which are influenced by sewage outlets, that the salinity ratios at the Afamia and Al Corniche aljanuby stations are lower than at the Higher Institute of Marine Research station year-round. This is due to the fact that these two stations are impacted by sewage water, which is less saline than seawater. Additionally, it is observed that the salinity ratios at these two stations decrease more significantly during the summer compared to the salinity ratio at the Higher Institute of Marine Research. This is attributed to the increase in seawater salinity during the summer, reaching (39.9‰) in August, as a result of rising evaporation levels, which reach (152.6 mm), while the salinity of sewage water remains relatively constant throughout the year.

Finally, the coastal waters of Syria are experiencing an increase in salinity due to long-term climate change. This exacerbates the global water cycle, leading to increased evaporation in some ocean areas (making them saltier) and increased precipitation and melting ice in other areas (making them fresher), although the specific impacts vary from region to region, affecting the ecosystem in the global ocean.

Conclusions and Recommendations:

1. The marine waters of the Latakia coast are part of the surface water mass (MAW) of Atlantic origin, with a thickness in Syrian territorial waters not exceeding (15m), and the horizontal distribution of the characteristics of these waters is marked by significant complexity.
2. The average salinity of the surface marine waters of the Latakia coast was (38.45‰), with variations throughout the different months of the year, influenced by various climatic factors. The salinity percentage at the station of the Higher Institute for Marine Research ranged between (37.5‰) and (39.9‰).
3. There is an inverse correlation between precipitation and the salinity of marine waters along the Latakia coast; as precipitation increases over the sea and surrounding areas, it leads to a dilution of the salts present in the seawater.
4. There is a direct correlation between evaporation and the salinity of marine waters along the Latakia coast, as the salinity percentage increases in water bodies where the evaporation rate is higher, meaning that water loss due to evaporation exceeds water intake from precipitation..
5. The salinity of the seawater along the Latakia coast decreases during winter due to the significant amount of precipitation (190 mm) in December, in addition to the river flows that enter the sea through the drainage funnel of the Tishreen Dam Lake (16).
6. The Pearson correlation coefficient between salinity levels and precipitation rate was calculated to be (-0.43), which supports the inverse relationship between these two variables.
7. The Pearson correlation coefficient value between salinity percentage and evaporation rate was (0.39), confirming the direct correlation between salinity percentage and evaporation rate.
8. The salinity of the seawater at the Afamia station ranged between (35.8‰) and (38.5‰), with the maximum salinity (38.5‰) recorded in November during the fall, and the minimum salinity (35.8‰) recorded in January during the winter.
9. The salinity of the seawater at the Al Corniche aljanuby station ranged between (37.9‰) and (35.6‰), with the maximum salinity (37.9‰) recorded in December during the winter, while the minimum salinity (35.6‰) was recorded in May during the spring.

10. The salinity levels at the Afamia and Al Corniche aljanuby stations are lower than those at the Higher Institute for Marine Research station throughout the year, due to the influence of sewage water at these two stations, which is less saline than seawater.

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