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Evolution of Groundwater Salinity in Northeast China; A GIS-Based Study

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Abstract

In arid and semi-arid regions, groundwater is the primary source for irrigation, drinking, and industrial use, yet water salinity and scarcity remain major challenges. However, no effort has been made to identify the natural and anthropogenic influences on groundwater salinity. In this brief background, the present study attempts to identify the factors and processes controlling the groundwater salinity in the Baicheng City, Jilin Province, China, from 2000, 2010, and 2018, using 7 hydrochemical parameters: electrical conductivity (EC), total dissolved solids (TDS), sodium (Na^+), chloride (Cl^-), bicarbonate (HCO_3^-), calcium (Ca^{2+}), and pH. Spatial distribution maps were generated using GIS-based interpolation, while linear regression analysis quantified the influence of chemical parameters on EC. The results reveal a significant increase in groundwater salinity over the study period. Non-saline areas declined from 40.0% (30,316.75km^2) in 2000 to 7.71% (1,987.22km^2) in 2018, whereas moderately saline areas expanded from 9.24% to 38.30%, becoming the dominant class. High- and very-high-salinity zones together accounted for 22–23% of the study area, primarily in southern Tongyu. Strong correlations between EC and TDS ($R^2 = 0.99$) and between EC and Ca^{2+} ($R^2 = 0.86$) highlight the primary chemical controls on salinity. The observed spatial patterns reflect the combined effects of natural hydrogeological factors and anthropogenic activities, including intensive irrigation and groundwater over-extraction. This integrated framework provides a robust basis for monitoring groundwater salinization and implementing targeted management strategies in semi-arid regions..

Keywords: Groundwater; Salinization; GIS; IDW; Baicheng city

Introduction

Groundwater is one of the most important freshwater resources for human activities, agriculture, and industrial purposes, particularly in semi-arid and arid areas. Microbial contamination frequently poses a safety challenge [1]. Salinity is currently increasing at a rate of 10% per year [2-6]. Numerous studies have demonstrated worldwide groundwater salinization, including in China [6-9], Pakistan [6-8], South America [9], and Australia [10]; in Africa: Morocco [11], Libya [12], and Egypt [7,8]. Therefore, reliable indicators are required to effectively evaluate and monitor groundwater salinity.

Electrical conductivity (EC) is widely used as a key indicator of groundwater salinity because it reflects the total dissolved salt concentration in water [9,10]. In combination with total dissolved solids (TDS) and major ions such as sodium (Na^+), chloride (Cl^-), calcium (Ca^{2+}), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}), EC provides a comprehensive understanding of hydrochemical processes controlling salinity [11-13]. The assessment of both spatial and temporal variations in these parameters is critical for identifying salinization hotspots, supply understanding chemical dynamics, and evaluating the potential impacts on agricultural lands and water.

Innovative tools, such as Geographic Information Systems (GIS), are crucial for effective management. GIS analysis visualizespatterns and the spatial distribution of groundwater quality parameters [14]. Spatial GIS analysis maps water resources and identifies contamination zones, enabling proactive groundwater protection [15-19]. IDW enables accurate estimation of groundwater salinity at unsampled locations, facilitating the identification of regions with high salinity levels and temporal changes over multiple years [20-23]. However, comprehensive assessments integrating spatial mapping, temporal trend analysis, and hydrochemical characterization remain limited.

This study focuses on the challenges faced by groundwater salinity in Baicheng City, Jilin Province China. Groundwater in northeastern China, particularly in Baicheng City, Jilin Province, has shown increasing salinity levels [24,25]. Baicheng City, represents a region where groundwater is a primary water resource for both agriculture and domestic use [26,27]. This study utilizes GIS and other analytical tools to comprehensively evaluate the challenges of sustainable groundwater management in arid environments, specifically in the Baicheng City.

This study focuses on evaluating the spatial and temporal evolution of groundwater salinity in Baicheng City from 2000 to 2018. By using groundwater EC, TDS, and major ion data, combined with GIS-based IDW interpolation and linear regression analysis, the study aims to:This study aims to provide a detailed evaluation of groundwater salinity dynamics in Baicheng City from 2000 to 2018. Specifically, (i) maps the spatial and temporal distribution of EC and major ions, (ii) examines the chemical controls on groundwater salinity using correlation and regression analyses, and (iii) identifies salinization hotspots to support targeted management strategies. The results provide a quantitative basis for sustainable groundwater management in Baicheng City and other semi-arid regions facing progressive salinization.

Materials and Methods

Description of study area

The study area is situated in the northwestern region of Jilin Province, China. It lies west of the Songnen Plain and east of the Horqin Grassland, between longitudes 121°38′–124°23′E and latitudes 44°13′–46°18′N including five counties: Tongyu, Taonan, Taobei, Da'an, and Zhenlai (Figure 1). The total study area was approximately 25,600Km2. Most of the area is flat and dominated by plains. The area has a temperate continental monsoon climate, with four different seasons, short autumns, and climate change within the last few decades. The wet season start from June to August, while spring and autumn are dry and windy, respectively. The average annual precipitation from 400-500mm, and the surface evaporation is high, with an average evaporation from 1000 to 2000mm [28], which is 3.5-4.75 times the annual average evaporation. Therefore, salt easily accumulates on the surface to form a saline soil [29].

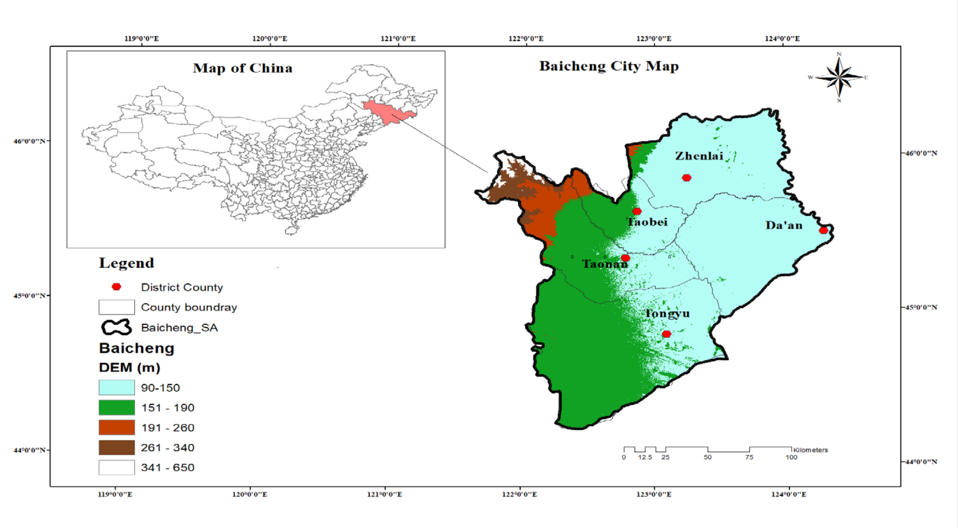

Figure 1: Location of the study region map.

Data source

Data has been collected from the Water Resources Department of Baicheng City, Jilin Province, China, covering the period from 2000 2010 and 2018. A total of 57 groundwater samples from 2000, 2010, and 2018 were obtained from the Water Resources Bureau of Baicheng City, Jilin Province, China. The dataset includes major physicochemical parameters such as electrical conductivity (EC), total dissolved solids (TDS), Na^+, Cl^-, HCO_3^-, Ca^{2+}, and pH, which were used to evaluate groundwater salinity.

The statistical data of groundwater and soil salinity-related parameters are summarized in Table 1.

Table 1: Statistical Summary of Groundwater data (2000-2018).

Factors	Units	2000		2010		2018	
		Min	Max	Min	Max	Min	Max
EC	μs/cm	305.8	637.96	292.72	731.32	222.65	795.8
TDS	mg/L	195.4	408.3	187.35	464.36	142.5	509.3
Na^+	mg/L	30	64.5	14.3	64.8	14.9	109.8
Cl^-	mg/L	18.5	85.8	10.7	85.8	15	119.9

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HCO_3^-	mg/L	112.8	113.6	116.8	272.76	89	225.8
Ca^{2+}	mg/L	15	45	21	87.6	23.6	74.7
pH		6.7	6.8	6.8	7.8	6.8	8.3

Assessment of soil salinity parameters

Electrical conductivity (EC) indicates the capacity of the soil solution and water to conduct electricity, which directly influences the concentration of soluble salts. EC is the basic measurement of salinity and is widely recognized as the criterion for assessing the effects of salt on crop yield and health [9]. It is commonly used to assess salinity; high EC indicates high salt concentration, which may affect plant water uptake by declining osmotic potential and inducing ion toxicity [30]. Total Dissolved Solids (TDS) is related to salinity and is commonly assessed by evaporating and weighing the soil solution; this method is more labor-intensive and less expedient than electrical conductivity (EC). A general conversion (TDS ≈ 640 × EC in mg/l) is used when salts such as NaCl predominate, although precision fluctuates with composition [9]. Sodium concentration directly influences the salinity and sodicity. The high Na^+ level can affect water quality and soil structure by causing clay dispersion and decreasing permeability [23,31]. It also increases osmotic stress on plants and may exacerbate nutritional imbalance [32]. Chloride concentration ions are directly linked with salinity; high Cl^- can induce specific ion toxicity, especially in certain sensitive crops, and, when combined with Na^+, they cause the issues of both sodicity and salinity [33]. Bicarbonate increases the precipitation and soil formation, including the formation of calcium carbonate, which affects soil quality, structure, and salinity dynamics [34]. It plays an important role in exchanging the sodium adsorption ratio (SAR). Calcium ions have adverse effects by improving clay flocculation. They also reduce sodicity and may reduce the salinity effects by removing Na^+ from soil exchange sites [35]. Bicarbonate ($HCO3^-$) affects the groundwater and are important in the precipitation of calcium carbonate [36]. pH level indicates the acidity or alkalinity, affecting the solubility the formation of minerals like calcium carbonate. High pH level may hence CaCO3 precipitation, impacting soil and groundwater properties and nutrient availability, especially in saline and irrigated conditions [23,32].

Temporal analysis using linear regression

To assess the long-term hydrochemical changes, linear regression analysis was applied to groundwater data (2000, 2010, and 2018). Each parameter (EC, TDS, Na^+, Cl^-, HCO_3^-, Ca^{2+}, pH) was determined by the following equation,

$$Y = aX + b \qquad (1)$$

where Y is the parameter value, X is the year, a is the intercept, and b is the slope. The coefficient of determination (R^2) quantified the proportion of temporal variation explained by the model, providing where Y is the parameter value, X is the year, a is the intercept, and b is the slope. The coefficient of determination (R^2) quantified the proportion of temporal variation explained by the model, providing insights into increasing trends in groundwater salinity and ion concentration over time [37,38]. Regression results were integrated with GIS-based interpolation to visualize temporal changes in EC and other parameters across 2000 to 2018.

GIS-Based spatial analysis

Data pre-processing

The Geographic Information System (GIS) plays a crucial role in the environmental field by integrating spatiotemporal data analysis with decision-making processes [39]. In this research, GIS was used for spatial and temporal analysis, which was conducted using ArcGIS 10.8 to analyze groundwater salinity factors. Groundwater data were stored in a spatial database and converted into point features for further analysis. To ensure spatial accuracy and consistency, all datasets were projected into the Xian_1980_GK_Zone_21 coordinate system. Data pre-processing included checking attribute consistency, correcting spatial errors, and preparing input datasets for spatial interpolation. Subsequently, spatial interpolation techniques were applied to generate continuous salinity distribution maps from point-based observations. These maps enabled the visualization of spatial variability and temporal changes in soil and groundwater salinity across the study area.

Spatial interpolation using IDW approach

Spatial Interpolation is a tool that use known point values to estimate unknown point values [40,41]. Interpolation tools are typically divided into geostatistical and deterministic approaches [41]. This study applied the Inverse Distance Weighting (IDW) interpolation method within a GIS framework to produce spatial distribution maps of salinity-related parameters, including electrical conductivity (EC), total dissolved solids (TDS), sodium (Na^+), chloride (Cl^-), bicarbonate (HCO_3^-), calcium (Ca^{2+}), and pH. The general IDW formula can be expressed as follows

$$Z(x_0) = \frac{\sum_{i=1}^{n} \frac{Z(x_i)}{d_i^p}}{\sum_{i=1}^{n} \frac{1}{d_i^p}} \qquad (2)$$

Whereas $Z(x_0)$ is estimated value for the unknown location at x_0, $Z(x_i)$ is the observed value at the known sample location at xi, di is the distance between the known and unknown point values and p is the power factor that controls the rate at which the influence of neighboring points decreases with distance.

The weight assigned to each known point is inversely proportional to its distance from the prediction location. As the power parameter increases, the influence of distant points decreases more rapidly, whereas lower power values produce a more uniform distribution of weights among neighboring points [42]. The overall flowchart of the adopted methodology is illustrated in Figure 2.

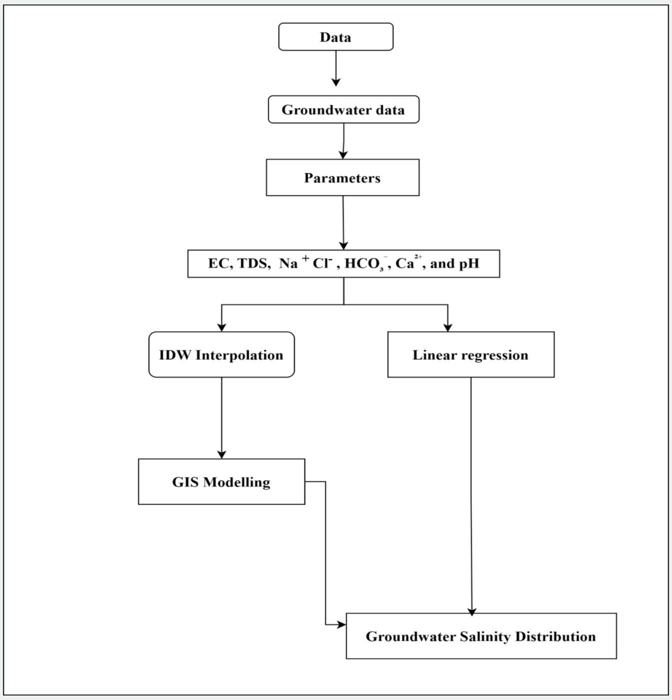

Figure 2: Schematic flowchart methodology.

Results

Spatial distribution of electrical conductivity (EC)

Distribution of EC in 2000

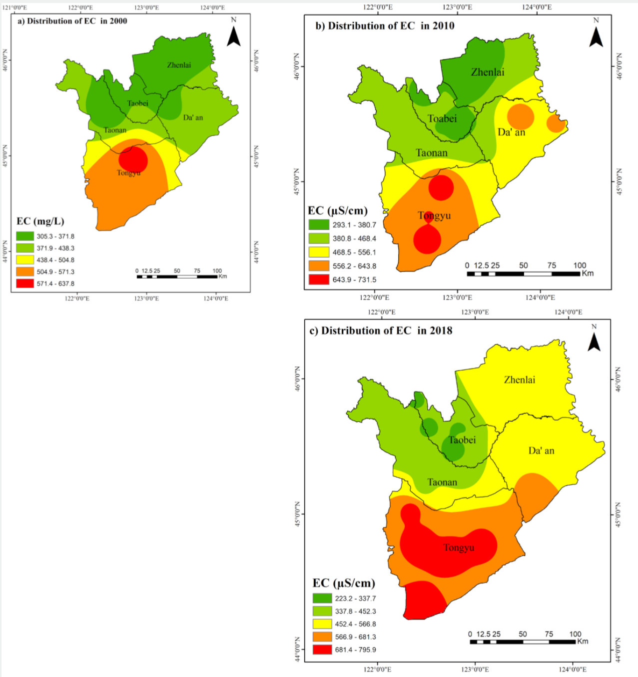

Figure 3: Spatial distribution of EC in (a) 2000, (b) 2010, and (c) 2018.

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In 2000, the spatial distribution of groundwater salinity based on EC in 2000 shows a clear north–south parts across the study area Figure 3a. The spatial distribution of groundwater salinity based on EC in 2000 shows a clear north–south gradient across the study area. Low EC values (non-saline to slightly saline) were mainly concentrated in the northern and north-central regions, particularly in Zhenlai and Taobei, while moderate EC levels occurred in the central areas around Taonan and Da'an. Higher EC concentrations were primarily observed in the southern region, especially in Tongyu. Non-saline areas covered 40.0% (30,316.75km^2) of the study area, followed by slightly saline areas at 24.13% (6,219.77km^2). Moderately saline zones accounted for 9.24% (2,445.42km^2), whereas high and very highly saline areas represented 22.80% (5,876.12km^2) and 3.53% (909.87km^2), respectively, mainly concentrated in the southern part of the study area.

Distribution of EC in 2010

The spatial distribution of EC in 2010 Figure 3b, shows a clear expansion of saline groundwater zones. Non-saline areas decreased to 20.22% (5,210.57km^2), mainly located in Zhenlai and Taobei. Slightly saline areas dominated the central region, including Taonan and parts of Da'an, covering 26.10% (6,727.27km^2). Moderately saline zones accounted for 18.18% (4,684.95km^2) and were mainly distributed in the central–southern transition areas. High salinity zones covered 19.32% (4,980.75km^2), while very highly saline areas increased to 16.16% (4,164.40km^2), primarily concentrated in Tongyu and southeastern Da'an.

Distribution of EC in 2018

The spatial distribution of EC in 2018 Figure 3c indicates a further expansion of groundwater salinity across the study area. Non-saline areas declined sharply to 7.71% (1,987.22km^2), remaining mainly in small patches in Taobei and northern Taonan. Slightly saline areas covered 20.07% (5,178.67km^2) and were mostly distributed in the northern and central regions. The moderately saline class became dominant, occupying 38.30% (9,870.15km^2), particularly across Taonan and Da'an. High salinity zones accounted for 11.14% (2,871.72km^2), while very highly saline areas expanded to 22.74% (5,860.18km^2), mainly concentrated in Tongyu and the southern parts. Overall, the results indicate a progressive deterioration of groundwater quality from 2000 to 2018, with increasing moderate and very high salinity levels.

Spatial distribution of total dissolved solids (TDS)

Distribution of TDS in 2000

The spatial distribution of groundwater salinity based on TDS in 2000 figure 4a, shows a pattern similar to EC. Non-saline groundwater dominated the northern areas, particularly Zhenlai and Taobei, covering 10,308.21km^2 (40.04%) of the study area. Slightly saline conditions were mainly distributed in the central regions, occupying 6,214.63km^2 (24.14%), while moderately saline areas accounted for 2,443.40km^2 (9.49%), primarily around Taonan. High salinity zones were concentrated in Tongyu, covering 5,871.26km^2 (22.80%), whereas very highly saline areas were limited to 909.12km^2 (3.53%), mainly occurring as localized hotspots in the southern part of the study area.

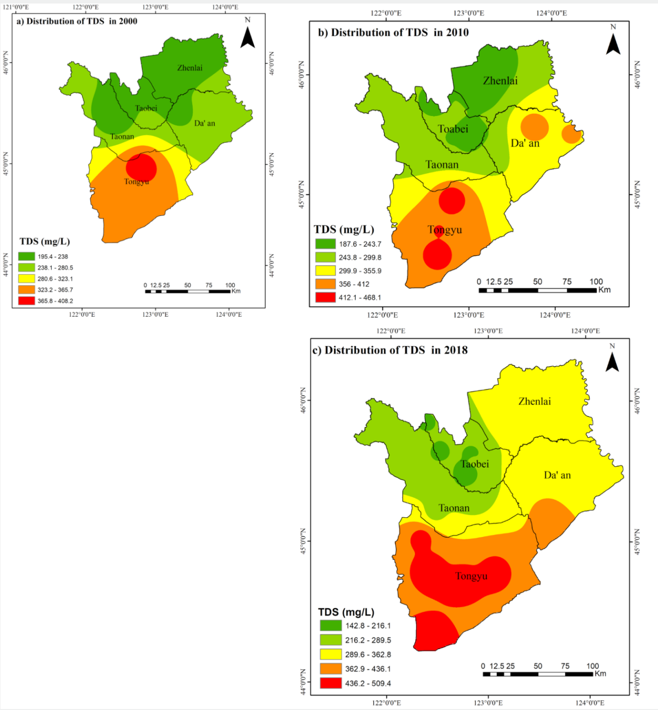

Figure 4: Spatial distribution TDS in (a) 2000, (b) 2010, and (c) 2018.

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Distribution of TDS in 2010

The spatial distribution of TDS in 2010 figure 4b, indicates an increase in groundwater salinity across the study area. Slightly saline areas became dominant, covering 6,721.71km^2 (26.11%), mainly in the central and northeastern regions. Non-saline areas decreased to 5,206.26km^2 (20.22%), remaining primarily in Zhenlai and parts of Taobei. Moderately saline zones expanded to 4,681.07km^2 (18.18%), mostly in the central transition areas. High salinity areas accounted for 4,976.63km^2 (19.33%), while very highly saline zones increased to 4,160.95km^2 (16.16%), mainly concentrated in Tongyu and southeastern Da'an.

Distribution of TDS in 2018

The spatial distribution of TDS in 2018 figure 4c, shows a clear dominance of moderately saline groundwater, covering 9,861.98km^2 (38.30%), mainly across Taonan and Da'an. Very highly saline areas increased to 5,855.33km^2 (22.74%), largely concentrated in Tongyu and southern regions. Slightly saline zones occupied 5,174.39km^2 (20.10%), mostly in the northern part of the study area. High salinity areas accounted for 2,869.35km^2 (11.14%), while non-saline areas declined sharply to 1,985.58km^2 (7.71%), indicating a significant reduction in fresh groundwater resources.

Spatial distribution of sodium (Na^+)

Distribution of Sodium Na+ in 2000

The spatial distribution of sodium (Na^+) in 2000 Figure 5a shows higher concentrations in the southern region, particularly in Tongyu, while lower levels occurred in the northern areas such as Zhenlai and Taobei. Non-saline areas covered 7,374.39km^2 (28.64%), followed by slightly saline zones with 4,765.83km^2 (18.51%). Moderately saline areas accounted for 4,513.01km^2 (17.53%), mainly in the central regions. High salinity zones occupied 3,121.44km^2 (12.12%), whereas very highly saline areas covered 5,971.95km^2 (23.20%), indicating considerable sodium accumulation in the southern groundwater systems.

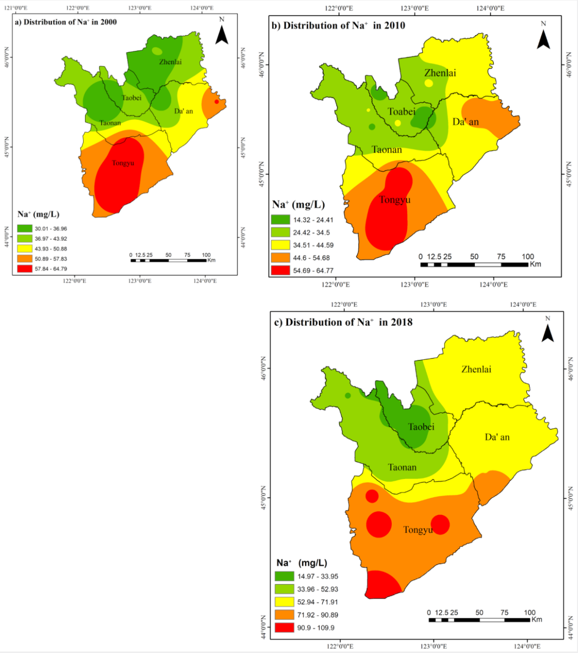

Figure 5: Spatial distribution of sodium (Na^+) in (a) 2000, (b) 2010, and (c) 2018.

Distribution of Sodium Na+ in 2010

The spatial distribution of Na^+ in 2010 Figure 5b indicates an expansion of moderate and high sodium concentrations. Moderately saline areas became dominant, covering 7,004.95km^2 (27.21%), mainly in the central and southern regions. Slightly saline zones accounted for 6,713.74km^2 (26.08%), while high salinity areas covered 5,505.44km^2 (21.38%). Very highly saline zones represented 4,603.56km^2 (17.88%), largely concentrated in Tongyu. Non-saline areas were limited to 1,918.94km^2 (7.45%), mostly in the northern regions.

Distribution of Sodium Na+ in 2018

The spatial distribution of Na^+ in 2018 Figure 5c shows a further expansion of salinity, with moderately saline areas dominating, covering 10,916.71km^2 (42.40%), mainly in Taonan and Da'an. High salinity zones accounted for 5,841.56km^2 (22.69%), while slightly saline areas covered 4,904.19km^2 (19.05%). Non-saline areas were limited to 2,204.35km^2 (8.56%), mostly in northern Zhenlai and Taobei, whereas very highly saline zones occupied 1,879.82km^2 (7.30%), primarily in southern Tongyu.

Spatial distribution of chloride (Cl^-)

Distribution of Chloride (Cl-) in 2000

In 2000 figure 6a, chloride concentrations exhibited a heterogeneous spatial pattern, with low levels in the northern regions (Zhenlai and Taobei) and higher concentrations in

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the south, particularly in Tongyu. Non-saline areas covered 4,999.81km^2 (19.42%), slightly saline zones 6,070.47km^2 (23.58%), and moderately saline areas 6,048.02km^2 (23.49%). High salinity zones accounted for 2,761.41km^2 (10.73%), while very highly saline areas occupied 5,866.92km^2 (22.79%), concentrated mainly in southern Tongyu.

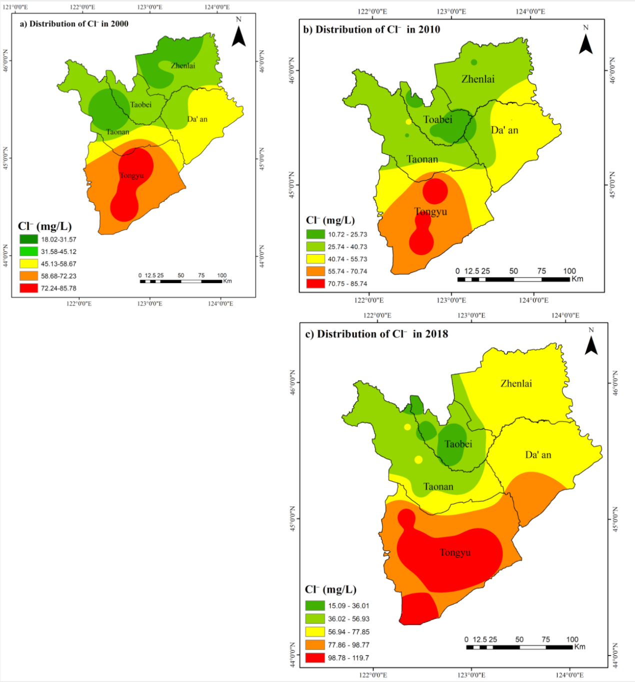

Figure 6: Spatial distribution of chloride (Cl⁻) in (a) 2000, (b) 2010, and (c) 2018.

Distribution of Chloride (Cl-) in 2010

By 2010 Figure 6b, slightly saline zones became dominant, covering 7,388.88km^2 (28.70%), while moderately saline areas accounted for 6,094.38km^2 (23.67%). Non-saline areas decreased to 4,883.18km^2 (18.97%). High salinity zones expanded to 3,406.85km^2 (13.23%), and very highly saline zones increased to 3,973.33km^2 (15.43%), largely in southern and southeastern regions, indicating a progressive salinization trend.

Distribution of Chloride (Cl-) in 2018

In 2018 Figure 6c, moderately saline areas became the most extensive class, covering 9,563.53km^2 (37.14%), mainly in central Taonan and Da'an. Very highly saline zones increased to 5,565.57km^2 (21.62%), concentrated in Tongyu, while slightly saline areas accounted for 4,623.85km^2 (17.96%). High salinity zones covered 3,430.76km^2 (13.33%), and non-saline areas were limited to 2,562.93km^2 (9.95%), primarily in the northern regions. Overall, the maps indicate a gradual southward expansion of high and very high chloride concentrations over the 18-year period.

Influence of hydrochemical parameters on groundwater salinity

Linear regression was performed to quantify the influence of major chemical parameters on EC (μS/cm), using TDS, Na^+, Cl^-, Ca^{2+}, HCO_3^-, and pH as independent variables Table 2, and the relationships between EC and the major parameters are illustrated in Figure 7. Regression analysis revealed a very strong correlation between EC and TDS (R^2 = 0.99), confirming that dissolved solids are the primary driver of groundwater salinity. Calcium also exhibited a strong correlation with EC (R^2 = 0.86), while pH showed a strong positive correlation (R^2 = 0.81). Sodium and chloride displayed moderate correlations with EC (R^2 = 0.63 and 0.56, respectively), indicating secondary contributions, whereas bicarbonate had a weak correlation (R^2 = 0.31), reflecting a minor effect.

Table 2: The mean value of hydrohychemical parameters from 2000 to 2018.

Years	EC	TDS	Na^+	Cl^-	HCO_3^-	Ca^{2+}	pH
2000	415.54	265.95	44.98	45.69	145.6	29.67	7.28
2010	463.22	296.46	37.38	40.39	175.66	43.03	7.4
2018	513.94	328.92	59.37	67.45	149.72	52.38	7.76

Overall, TDS and Ca^{2+} are the dominant factors controlling EC, with Na^+, Cl^-, and pH exerting moderate effects, and HCO_3^- contributing minimally. These results are consistent with the spatial distribution patterns, providing a quantitative basis for understanding the chemical controls on groundwater salinization in Baicheng City.

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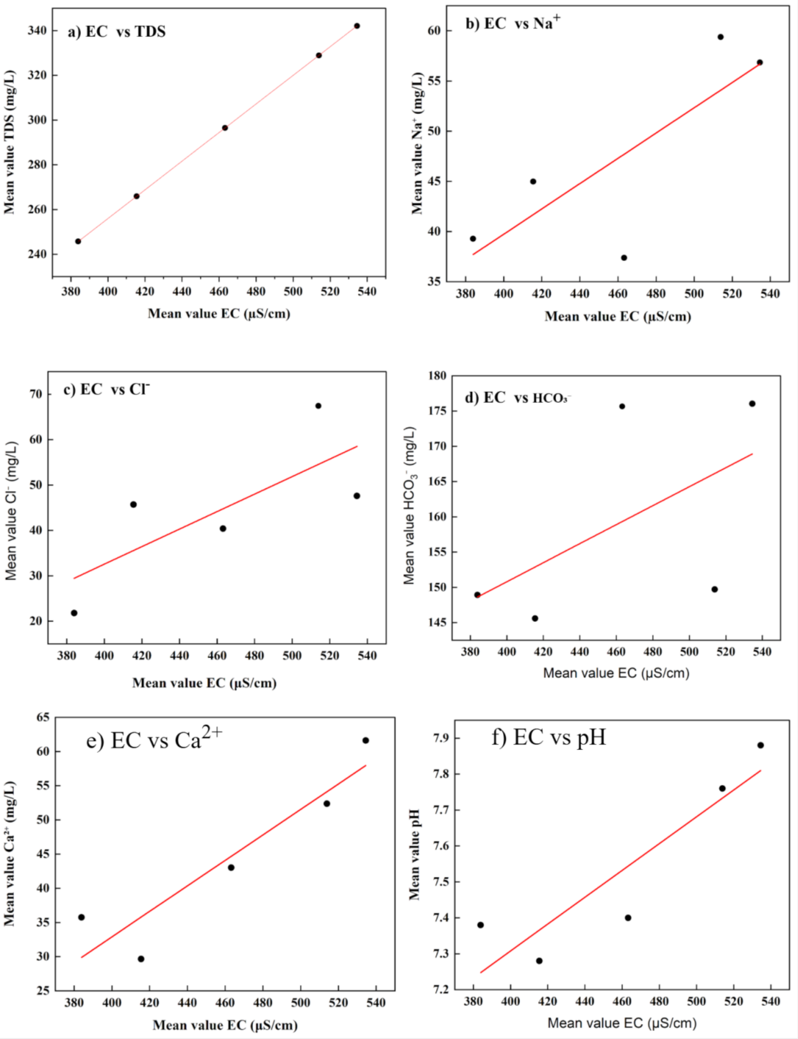

Figure 7: The relationship between electrical conductivity (EC, µS/cm) and major groundwater ions: (a) EC vs TDS, (b) EC vs Na, (c) EC vs Cl-, (d) EC vs HCO_3^-, (e) EC vs Ca^{2+}, and (f) EC vs pH respectively.

Discussion

The spatio-temporal analysis of groundwater salinity in Baicheng City reveals distinct patterns between 2000, 2010, and 2018. Low to moderate EC (<380µS/cm) and TDS (<240mg/L) values dominated the northern and central regions, whereas southern Tongyu remained the most affected area. This pattern is consistent with studies conducted in semi-arid regions of Northeast China, where low-lying plains and areas with intensive irrigation are prone to salinity accumulation due to high evapotranspiration and limited groundwater recharge [43-45].

Hydrochemical analysis indicates that TDS is the primary factor controlling EC, reflecting the dominant influence of dissolved ionic concentrations on groundwater salinity [46,47]. Calcium (Ca^{2+}) and pH show strong correlations with EC, highlighting their roles in hydrochemical processes and salt solubility [49,49]. Sodium (Na^+) and chloride (Cl^-) exhibit moderate correlations, suggesting a secondary contribution to salinity, whereas bicarbonate (HCO_3^-) shows a relatively weak relationship with EC [49,50]. These results are consistent with the spatial distribution maps, where high EC values coincide with elevated TDS and Ca^{2+} concentrations.

The observed salinization pattern is influenced by both natural hydrogeological conditions and anthropogenic activities [51]. The flat topography of southern Tongyu, combined with intensive irrigation and groundwater over-extraction, promotes salt accumulation, while regional groundwater flow may facilitate the northward migration of salinity [52]. These findings indicate that groundwater salinization in the study area is both localized and progressive.

From a management perspective, these results highlight the importance of regulating groundwater extraction, improving irrigation practices to minimize salt accumulation, and implementing targeted mitigation strategies in high-salinity zones [53-55]. Understanding the key chemical drivers of salinity, particularly TDS and Ca^{2+}, can support the development of more effective groundwater management and remediation strategies.

Conclusion

This study assessed the spatial and temporal dynamics of groundwater salinity in Baicheng City, from 2000, 2010, to 2018. The results reveal a clear increase in salinity, with high-salinity zones consistently concentrated in southern Tongyu and gradually expanding northward and eastward, indicating the vulnerability of low-lying plains to progressive salinization. Hydrochemical analysis shows that total dissolved solids (TDS) are the dominant contributor to electrical conductivity (EC), while calcium (Ca^{2+}) and pH exert strong influences on groundwater salinity. Sodium (Na^{+}) and chloride (Cl^{-}) show moderate contributions, whereas bicarbonate (HCO_3^{-}) has a relatively minor effect. The spatial patterns reflect the combined influence of natural hydrogeological conditions, including topography and groundwater flow, and human activities such as intensive irrigation and groundwater over-extraction. These findings highlight the need for improved groundwater management, including regulated pumping, optimized irrigation practices, and continuous monitoring of hydrochemical parameters to mitigate salinization and protect water resources in Baicheng City and similar semi-arid regions.

Author Contribution

Conceptualization, M.S., Z.F. and Y.S.; Data curation and software, M.S.; Formal analysis, Y.S. and K.H.; Supervision, Z.F.; Validation, Z.M. and K.H.; Review and editing, M.S.; Visualization, Y.S. and K.H.; Writing—Original draft, M.S.; Writing—Review and editing, Y.S. and K.H. All authors have read and agreed to publish this version of the manuscript.

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Data Availability

The data presented in this study are available upon request from the corresponding author.

Declaration

Ethics Approval: Not applicable.

Consent to Participate: All authors reviewed and approved the final manuscript.

Competing Interests: The authors declare no competing interests.

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