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Corrosivity of groundwater and its implications for material degradation in water distribution systems

ABSTRACT

A complete study of groundwater quality and corrosion potential was conducted in Theni District, Tamil Nadu, using 37 water samples collected from nine locations between March and April 2025. 23 physicochemical parameters and 4 metal ions were analyzed as per standard procedure, The scaling and corrosive tendency of water was analyzed by seven corrosion indices including Langelier Saturation Index (LSI), Ryznar Stability Index (RSI), Puckorius Scaling Index (PSI), Potential to Promote Galvanic Corrosion (PPGC), Larson Skold Index (LI), Aggressiveness Index (AI) and Corrosivity Ratio (CR). Results showed that LSI, PSI, RSI, and PPGC consistently indicated corrosive water, whereas the remaining indices reflected a range from scaling to moderate corrosion, illustrating spatial variability of pH, alkalinity, chloride and sulphate concentrations. GIS study of physicochemical parameters found that samples from Uthamapalayam, Allinagaram, Thevaram, and Aundipatty were above the limits, indicating corrosive water conditions. While zinc, copper, and lead levels were within acceptable ranges, iron levels at Kumuli, Gudalur, and Cumbum exceeded WHO criteria, most likely due to pipeline corrosion under aggressive groundwater conditions. Nonmetallic piping such as PVC or corrosion-resistant materials such as stainless steel are recommended to extend pipe life. The findings include a quantitative assessment of corrosion risk in the Theni District, as well as information on water treatment and infrastructure protection methods.

Keywords: *Water quality parameters, corrosivity indices, theni district, GIS*

INTRODUCTION

India is endowed with a diverse range of natural resources, including "water." Water is not only necessary for the survival of animals and plants, but it also holds a special place in industry [1]. Water has a certain beauty that is both aesthetically pleasing and intellectually stimulating. According to Sarala Thambavani et al [2], ground water is currently used more often than surface water to meet household, agricultural, and industrial water demands. The primary source of drinking water in our nation and an essential component of our existence is groundwater. Serious socioeconomic repercussions emerge from the overuse of groundwater, which lowers the groundwater table and degrades groundwater quality due to human activity [3]. The suitability of water for a particular use is determined by specified water quality criteria. Groundwater has certain qualities that make it appropriate for use as a public water supply [4].

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Recent research highlights the need to evaluate chemical stability in addition to standard potability parameters when evaluating groundwater quality, especially when it comes to corrosion and scaling in water supply systems. Corrosive water poses risks to infrastructure sustainability and public health by accelerating pipeline deterioration, facilitating metal leaching, and decreasing hydraulic efficiency, enhancing the release and accumulation of metals and increasing maintenance. The toxicity of metals and their buildup in aquatic ecosystems have made it a topic of growing concern [5]. The use of corrosion indices is a useful supplementary strategy since traditional water quality parameters might not adequately capture these risks. Analytical terms like Ryznar stability index (RSI), Aggressive index (AI), Langelier saturation index (LSI), LarsonSkold index (LI), and Puckorius scaling index (PSI) can be used to predict water corrosion and scaling.[6.7]. Groundwater and surface water corrosion and scaling potential have been the subject of several research [8-11]. Additionally, GIS allows for the geographical analysis and visualisation of groundwater quality, which aids in the identification of regions with poor water conditions. The use of GIS techniques and spatial statistics for mapping groundwater quality parameters and identifying regions at risk for groundwater pollution has been shown in recent literature [12,13].

The entire Theni district in southern Tamil Nadu, which is mostly a hard-rock aquifer region that uses groundwater mostly for agriculture. Concerns over the deteriorating quality of groundwater in this region have been highlighted by the growing usage of fertilizers and the ongoing rate of groundwater removal. There has been research on the hydrochemical properties regarding groundwater in the states of southern India , but there is a lack of information in the literature about studies that use GIS-based spatial modelling and evaluate corrosion index values in addition to hydrochemical evaluation in the Theni District. To fill these gaps, this study will use commonly used corrosion indices and GIS technologies to assess groundwater quality in Theni District and its potential for scaling and corrosion.

MATERIALS AND METHODS

Description of the Study Site

The research was investigated in Theni District, located in the Southwestern part of Tamil Nadu, India. The district's geography is located between 9°30' and 10°30' N Latitude; and 77°00' and 77°30' E Longitude covering approximately 3,200 km². The district has a semi-arid to sub-humid climate, with the majority of rainfall occurring from the southwest and northeast monsoon systems.

Precambrian crystalline rocks dominate the geological attributes of Theni District and include primarily charnockite, granitic gneiss, hornblende – biotite gneiss, and migmatitic complexes. The consolidated nature of these rocks limits the potential for primary porosity to allow groundwater to be stored until it is replenished by secondary processes that take place through weathering and fracturing. Geomorphologically, the landscape of Theni District presents assorted landforms that developed because of long-term tectonic shifts and erosion; they were not created suddenly by an event. The area drains primarily via the Vaigai River Basin, and the entire pattern of drainage among these features can be considered dendritic to sub-dendritic in most cases due to the influence of geomorphologic conditions and structural controls that affect lithological uniformity across the district. Groundwater is the main source of crop irrigation, and most people are employed in agriculture. Rapid population growth, increased agricultural intensity, and high rates of groundwater resource extraction have put stress on groundwater supplies in addition to the production of crops like paddy, sugarcane, bananas, pulses, and vegetables.

Sampling and analysis

Nine different locations were used to collect 37 groundwater samples: Kumuli (S1–S5), Gudalur (S6–S9), Cumbum (S10–S12), Uthamapalayam (S13–S14), Thevaram (S15–S20), Bodimettu (S21–S27), Allinagaram (S28–S29), Aundipatty (S30–S35), and Melmangalam (S36–S37). Samples were collected between March and April 2025 to assess the water quality and corrosion potential of the five Taluks in the Theni District (Table 1).To sufficiently cover the entire area, sampling locations were chosen to represent the district's primary aquifers as well as the primary domestic and agricultural water supply zones. Each water sample was collected and placed into previously cleaned 1 L polyethylene bottles to avoid contamination. The bottles were then rinsed three times with source water. Samples for cation analysis were preserved by adding 1 mL of nitric acid to each liter of water to avoid precipitation, while anion samples were not acidified.

Water samples were analyzed in accordance with the American Public Health Association standard methods[14]. On-site measurements for pH, electrical conductivity (EC), and temperature were conducted utilizing a portable multiparameter probe (Hanna HI98194) to obtain the measurements. The turbidity of the samples was determined utilizing a Nephelometric method. Total dissolved solids (TDS) of the samples were determined through filtration and a gravimetric method. The concentrations of major cations (Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), and Potassium (K^{+})) were obtained using a flame photometer (Systronics FP 641), while the concentrations of Bicarbonate (HCO_3^{-}), Carbonate (CO_3^{2-}), and Alkalinity were determined by titration of the filtered water samples with Standardized HCl. The Total Hardness of the samples was assessed by titration with EDTA (Ethylene Diamine Tetra Acetic acid). The concentrations of Chloride (Cl^{-}) and Sulphate (SO_4^{2-}) in the samples were determined through argentometric titration and Ultraviolet-Visible (UV-Vis) spectroscopy (Shimadzu UV-1800), respectively. Phosphate was measured spectrophotometrically with the acid molybdate method, nitrate was measured using the Cadmium reduction method, and Fluoride was measured by the SPADNS (Sodium 2-(Parasulphophenyl Azo)-1, 8 Dihydroxy-3, 6 Naphthalene Disulphonate).

Dissolved Oxygen (DO) was measured using the Winkler iodometric method, whereas Biochemical Oxygen Demand (BOD) was determined after an incubation period of five days at a temperature of 20 °C. Chemical Oxygen Demand (COD) was obtained with acidified $K_2Cr_2O_7$. Metalionconcentrationsfor Zinc, Copper, and Lead were quantitatively determined usinganAtomicAbsorption Spectrophotometer (ELICO Model SL-168) andtheconcentration of Iron having been determined viaa Shimadzu UV–1800 spectrophotometer.

Table 1. Details of sampling points

S. No	Name of the Taluk	Location	Sampling points
1	Uthamapalayam	Kumuli	S1 to S5
		Gudalur	S6 to S9
		Cumbum	S10 to S12
		Uthamapalayam	S13 and S14
		Thevaram	S15 to S20
2	Bodinayakkanur	Bodimettu	S21 to S27
3	Theni	Allinagaram	S28 and S29
4	Aundipatty	Aundipatty	S30 to S35
5	Periyakulam	Melmangalam	S36 to S37

The use of steel and cast iron distribution pipelines in Theni District, allows for the use of corrosivity indices to identify the potential for corrosion. Seven corrosion indices are utilized to evaluate the potential for groundwater corrosion and scaling, including: the Potential to Promote Galvanic Corrosion (PPGC), Larson Skold Index (LI), Aggressiveness Index (AI), Puckorius Scaling Index (PSI), Ryznar Stability Index (RSI), Corrosivity Ratio (CR) and Langelier Saturation Index (LSI), which were calculated from laboratory-measured physicochemical parameters (Table 2). The values obtained from these indices serve as indicators of the tendency of groundwater to cause corrosion of distribution pipes or develop scale within water distribution systems.

Hydrochemical evaluations of spatial distributions of groundwater quality within Theni District were performed using QGIS version 3.30. Continuous maps of hydrochemical parameters across the district were generated using interpolation techniques (Inverse Distance Weighted [IDW] and Kriging) to assist with identifying areas with high concentrations of water quality parameters. Fig. 1 presents a map of the study area and the 37 groundwater sampling sites around Theni District.

The combination of laboratory analyses, corrosion indices, and GIS-based spatial mapping can be used as a comprehensive assessment of groundwater quality and stability, allowing for the development of better-informed strategies for managing and utilizing groundwater sustainability within Theni District.

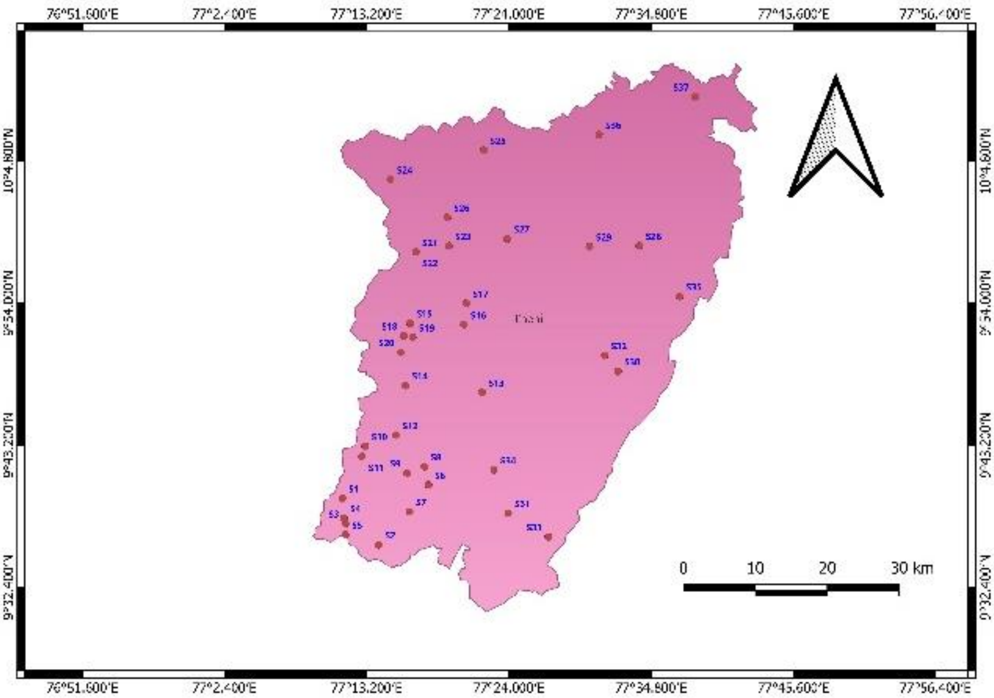

Figure 1. Map of the study area with sampling sites

Table 2. Indices to evaluate corrosivity nature of water

Corrosion Index	Formula	Interpretation	Ref.
Langelier Saturation Index (LSI)	$LSI = P^H - P_S^H$ $pHs = (9.3 + A + B) - (C + D)$ $A = (log_{10}(TDS) - 1)/10$ $B = -13.12\ log_{10}(T + 273) + 34.55)$ $C = log_{10}(Ca^{2+}) - 0.4$ $D = log_{10}(Alk)$	LSI > 0 Scale formation LSI = 0 Neutral LSI < 0 Corrosive	[15]
Ryznar Stability Index (RSI)	$RSI = 2\ x\ pHs - pH$	RSI < 6 Scale formation RSI 6–7 Neutral RSI >7 Corrosive	[16]
Puckorius Scaling Index (PSI)	$PSI = 2\ x\ pHeq - pHs$ $pHeq = 1.465\ x\ Log_{10}(Alkalinity) + 4.54$	PSI < 6 Scale formation PSI > 6 Corrosive	[17]
Potential to Promote Galvanic Corrosion (PPGC)	$PPGC = (Cl^-)/(SO_4{}^{2-})$ (all in mg/L)	PPGC < 0.5 Low galvanic corrosion risk PPGC >0.5 High galvanic corrosion risk	[18]
Larson Skold Index (LS)	$LI = \frac{(Cl^-)+(SO_4^{2-})}{(CO_3^{2-}+HCO_3^-)}$ (all in meq/L)	LI < 0.8 Low corrosion risk LI + 0.8–1.2 Moderate corrosion risk LI > 1.2 High corrosion risk	[19]
Aggressiveness Index (AI)	$AI = pH + log_{10}[A\ x\ H]$ A = alkalinity as $CaCO_3$ (mg/L) H = hardness as $CaCO_3$ (mg/L)	AI < 10 Highly aggressive AI =10–12 Moderately aggressive AI > 12 Non-aggressive	[20]
Corrosivity Ratio (CR)	$CR = \frac{0.028(Cl) + 0.021\ (SO_4)}{0.02\ (HCO_3 +\ CO_3)}$	CR <1= Non corrosive CR>1 = Corrosive	[16]

RESULTS AND DISCUSSION

Water quality parameters

The research area's water temperature varied between 16.7 and 24.6 °C, according to an investigation of water quality characteristics. It was found that all of the water samples were colorless and odorless. Every sample's turbidity levels were found to be within the acceptable limit of 5.0 NTU.

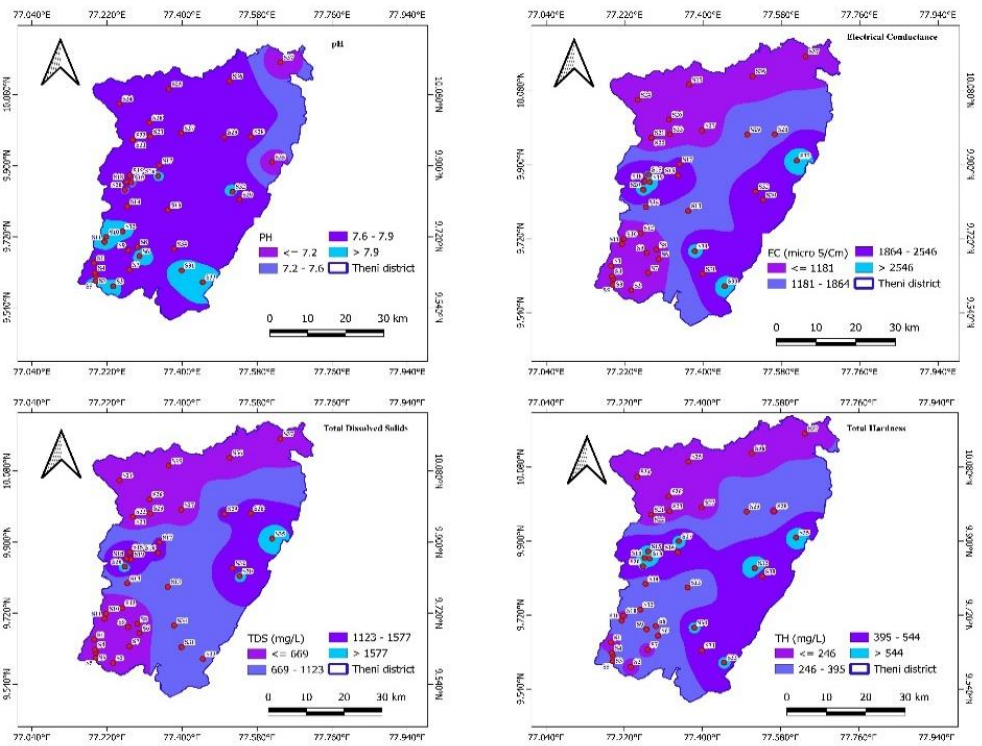

Figure 2. Spatial distribution of a) pH b) EC c) TDS d) TH

Every sample's pH fell between the acceptable range of 6.5 and 8.5. Spatial mapping revealed that Uthamapalayam, Thevaram, Allinagaram, and Aundipatty had higher electrical conductance (EC), ranging from 325 to 3258 µS/cm.A similar trend was seen in the geographical distribution of total dissolved solids (TDS), which varied from 214 to 2038 mg/L.The range of total hardness was 96 to 693 mg/L.The samples from Thevaram and Aundipatty exceeded the limit of 300mg/L (Fig.2).

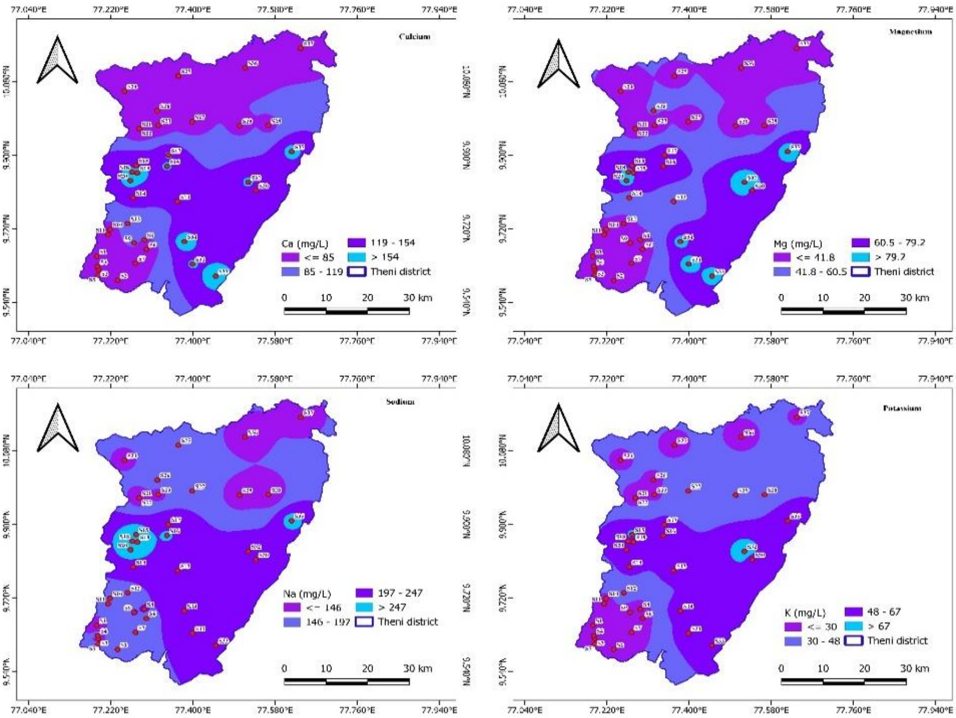

Figure 3. Spatial distribution of a) Ca b) Mg c) Na d) K

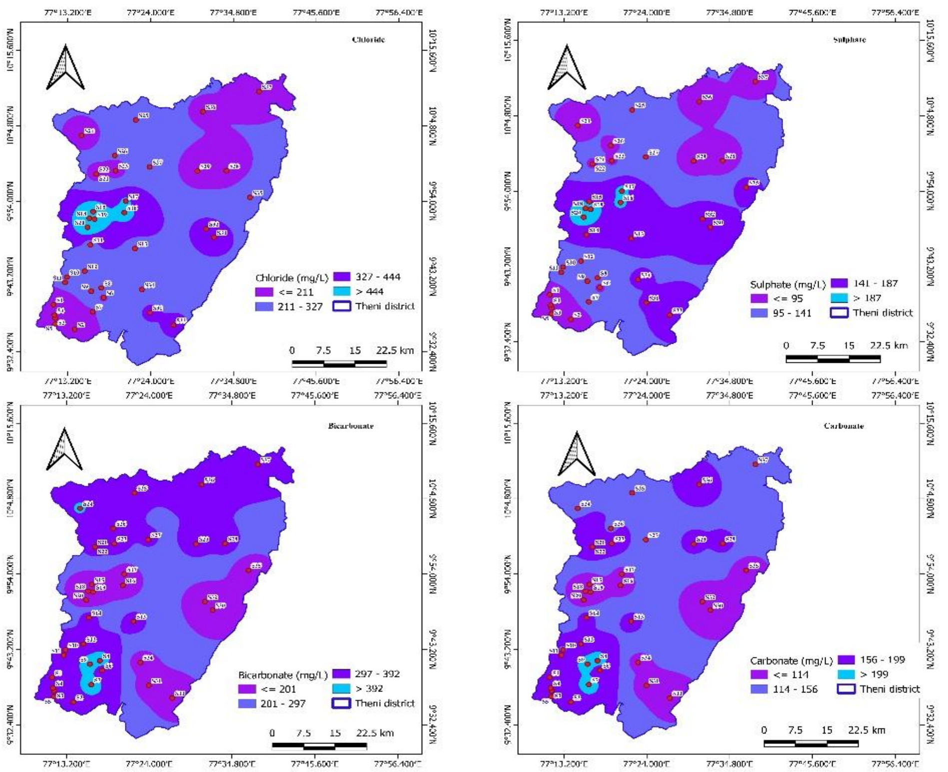

Figure 4. Spatial distribution of a) Chloride b) Sulphate c) Bicarbonate d) Carbonate

According to major cations (Fig. 3), nearly all of the samples showed magnesium concentration above 30 mg/L, while many samples from Kumuli, Gudalur, Uthamapalayam, Thevaram, Allinagaram, and Aundipatty had calcium concentrations above 75 mg/L. Thevaram, Allinagaram, Aundipatty, and Uthamapalayam all have elevated potassium and sodium levels.. Anions showed variation: sulphate varied from 48 to 236 mg/L, with higher levels in Thevaram; chloride ranged from 92 to 567 mg/L, with the highest values in Uthamapalayam, Allinagaram, and Aundipatty.Bicarbonate concentrations varied from 105 to 493 mg/L, exceeding 300 mg/L in samples from Uthamapalayam, Thevaram, Allinagaram, Bodimettu, and Melmangalam whereas carbonate ranged from 71 to 244 mg/L, showing a similar spatial distribution (Fig.4). The concentration of fluoride varied from 0.23 to 0.93 mg/L.

The use of agrochemicals is most likely the cause of localised eutrophication indices like phosphate (0.49 to 1.98 mg/L) and nitrate (0.56 to 1.95 mg/L) (Fig. 5).The biochemical oxygen demand (BOD) ranged from 1.1 to 3.9 mg/L, while the dissolved oxygen (DO) ranged from 2.5 to 6.8 mg/L.Thevaram and Aundipatty had higher BOD, indicating lower water quality in these regions because of sewage percolation (Fig. 6).

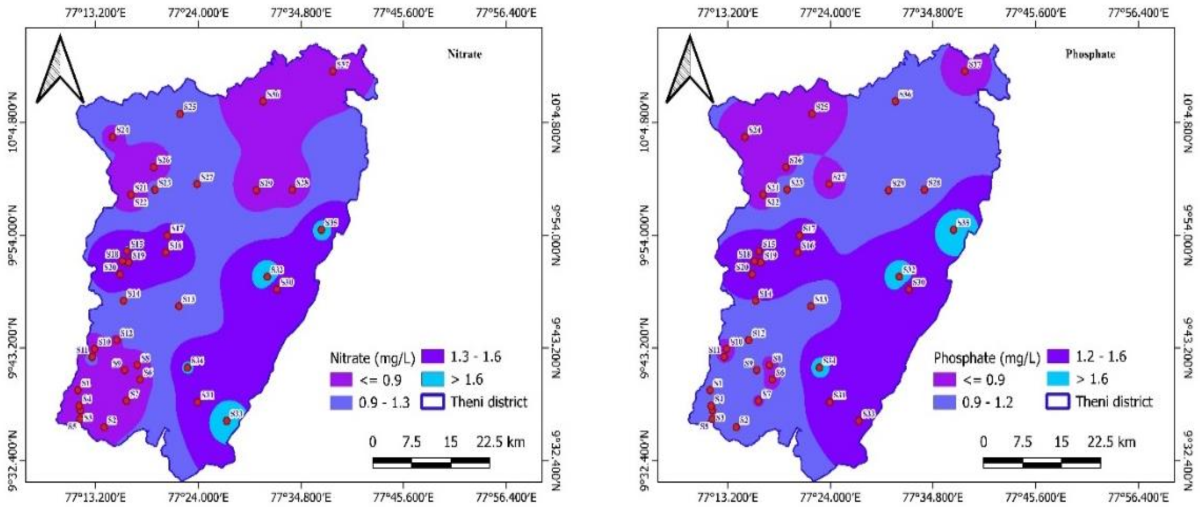

Figure 5. Spatial distribution of a) Nitrate b) Phosphate

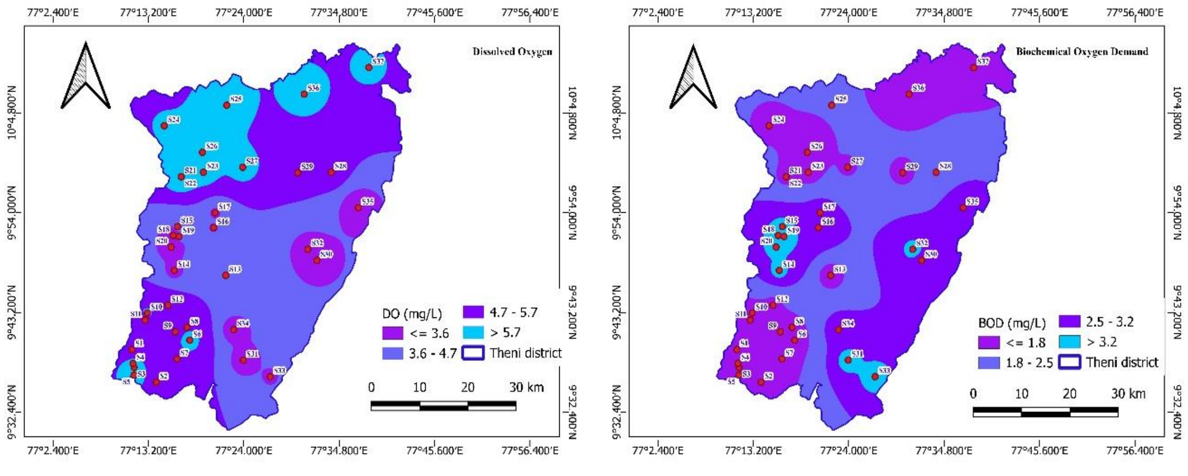

Figure 6. Spatial distribution of a) DO b) BOD

The metal concentration of zinc, copper, lead showed within the limits of WHO [21] in all the sampling sites reported that the metal contents in water samples may be due to geogenic sources. Iron levels at Kumuli, Gudalur, and Cumbum were higher than the WHO limit of 0.3 mg/L, indicating the effect of corrosion (Fig.7). This may result from iron leaching due to corrosive groundwater conditions and the aging of iron pipes.

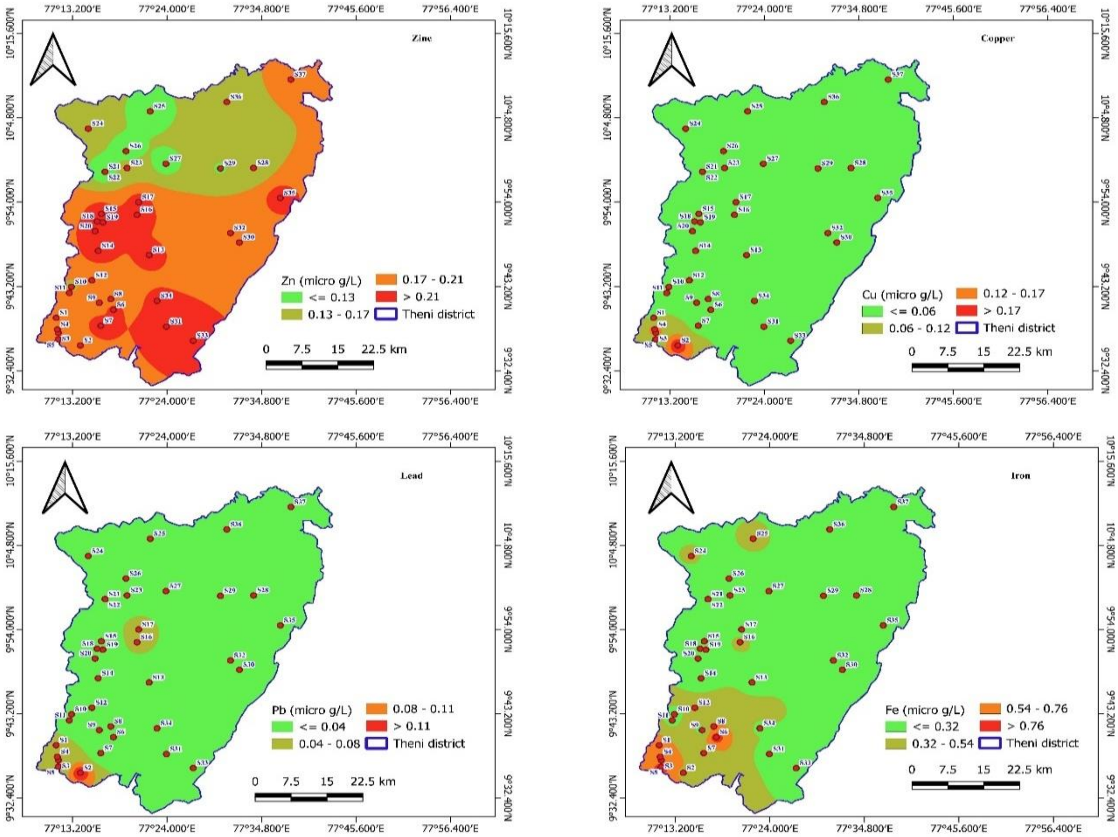

Figure 7. Spatial distribution of metal concentrations a) Zn b) Cu c) Pb d) Fe

CORROSIVITY INDICES

Langelier Saturation Index (LSI)

In the present investigation, all analyzed water samples exhibited negative Langelier Saturation Index (LSI) values, ranging from –3.94 to –1.57, with a mean of –2.42, clearly indicating that the water is undersaturated with respect to calcium carbonate and has a pronounced tendency toward corrosion rather than scale formation. Such negative LSI values reflect a significant potential for the water to dissolve protective carbonate layers and promote corrosive attack on metallic infrastructure within distribution systems. These results are consistent with recent studies reporting negative LSI values (–3.84 to –0.93), indicating corrosive water conditions, as observed in spring waters of Southern Poland [22].

Ryznar Stability Index (RSI)

The Ryznar Stability Index (RSI) values for all samples were greater than 7, confirming a pronounced corrosive nature of the water. RSI values ranged from 11.25 to 14.72, with a mean of 12.61, indicating highly aggressive conditions and low calcium carbonate stability. These findings are consistent with the negative Langelier Saturation Index (LSI) values, which also indicate undersaturation with respect to $CaCO_3$ and a strong tendency toward corrosion rather than scale formation.

Puckorius Scaling Index (PSI)

The PSI values varied from 11.07 to 14.11, with an average of 12.34, suggesting highly aggressive water chemistry with poor buffering capacity and dominant corrosive tendency of the water. Elevated PSI values reflect low calcium carbonate precipitation potential under equilibrium conditions, implying that the water is unlikely to form protective scale layers and instead may enhance corrosion on pipes and distribution infrastructure. This pattern is consistent with the negative LSI values and high RSI values, all of which collectively confirm the prevalence of corrosive water conditions across the study area. Based on PSI values, Farzadkia et al. [23] determined that Malekshahi City's drinking water was corrosive; these conclusions align with the current study's findings.

Potential to Promote Galvanic Corrosion (PPGC)

Galvanic corrosion was evident in every water sample, with an average PPGC of 2.17 and a range of 1.50 to 3.16. These samples' high chloride content suggests that metal pipes and fittings are more vulnerable to corrosion, underscoring the importance of water treatment or damage-prevention strategies.

Table 3. Summary of calculated corrosivity indices

SS	LSI	Inference	RSI	Inference	PSI	Inference	PPGC	Inference	LI	Inference	AI	Inference	CR	Inference
S1	-2.11	Corrosion	12.01	Corrosion	11.53	Corrosion	1.92	Galvanic corrosion	0.26	Scale	12.18	Non aggressive	0.34	Non corrosive
S2	-1.84	Corrosion	11.69	Corrosion	11.39	Corrosion	2.41	Galvanic corrosion	0.32	Scale	12.4	Non aggressive	0.42	Non corrosive
S3	-2.00	Corrosion	11.9	Corrosion	11.5	Corrosion	2.1	Galvanic corrosion	0.27	Scale	12.22	Non aggressive	0.35	Non corrosive
S4	-2.37	Corrosion	12.44	Corrosion	11.95	Corrosion	1.77	Galvanic corrosion	0.55	Scale	12.09	Non aggressive	0.71	Non corrosive
S5	-2.19	Corrosion	12.47	Corrosion	12.37	Corrosion	1.78	Galvanic corrosion	0.57	Scale	12.35	Non aggressive	0.73	Non corrosive
S6	-2.19	Corrosion	12.58	Corrosion	12.59	Corrosion	2.34	Galvanic corrosion	0.62	Scale	12.41	Non aggressive	0.82	Non corrosive
S7	-2.44	Corrosion	12.47	Corrosion	11.61	Corrosion	2.02	Galvanic corrosion	0.44	Scale	12.09	Non aggressive	0.58	Non corrosive
S8	-1.88	Corrosion	11.66	Corrosion	11.07	Corrosion	2.07	Galvanic corrosion	0.44	Scale	12.53	Non aggressive	0.57	Non corrosive
S9	-2.21	Corrosion	12.03	Corrosion	11.15	Corrosion	2.09	Galvanic corrosion	0.46	Scale	12.23	Non aggressive	0.6	Non corrosive
S10	-1.64	Corrosion	11.59	Corrosion	11.7	Corrosion	2.41	Galvanic corrosion	0.76	Scale	12.66	Non aggressive	0.9	Non corrosive
S11	-1.98	Corrosion	11.85	Corrosion	11.54	Corrosion	1.86	Galvanic corrosion	0.69	Scale	12.3	Non aggressive	0.89	Non corrosive
S12	-1.57	Corrosion	11.25	Corrosion	11.16	Corrosion	1.78	Galvanic corrosion	0.75	Scale	12.57	Non aggressive	0.97	Non corrosive
S13	-2.46	Corrosion	12.52	Corrosion	11.85	Corrosion	1.82	Galvanic corrosion	0.83	Corrosion	12.24	Non aggressive	1.07	Corrosive
S14	-2.22	Corrosion	12.24	Corrosion	11.75	Corrosion	1.78	Galvanic corrosion	0.81	Corrosion	12.49	Non aggressive	1.05	Corrosive
S15	-3.13	Corrosion	13.95	Corrosion	14.11	Corrosion	3.16	Galvanic corrosion	3.74	High corrosion	11.9	Non aggressive	4.96	Corrosive
S16	-2.59	Corrosion	13.17	Corrosion	13.61	Corrosion	2.67	Galvanic corrosion	3.56	High corrosion	12.26	Non aggressive	4.69	Corrosive
S17	-2.68	Corrosion	13.25	Corrosion	13.58	Corrosion	2.26	Galvanic corrosion	3.06	High corrosion	12.17	Non aggressive	4.01	Corrosive
S18	-2.76	Corrosion	13.32	Corrosion	13.52	Corrosion	2.28	Galvanic corrosion	3.47	High corrosion	12.11	Non aggressive	4.54	Corrosive

S19	-3.09	Corrosion	13.59	Corrosion	13.45	Corrosion	2.7	Galvanic corrosion	3.8	High corrosion	11.72	Non aggressive	5.01	Corrosive
S20	-3.23	Corrosion	13.95	Corrosion	13.85	Corrosion	2.4	Galvanic corrosion	3.79	High corrosion	11.82	Non aggressive	4.97	Corrosive
S21	-2.09	Corrosion	12.09	Corrosion	11.77	Corrosion	2.55	Galvanic corrosion	0.59	Scale	12.16	Non aggressive	0.78	Non corrosive
S22	-2.36	Corrosion	12.36	Corrosion	11.79	Corrosion	1.5	Galvanic corrosion	0.46	Scale	11.88	Non aggressive	0.59	Non corrosive
S23	-2.16	Corrosion	11.94	Corrosion	11.2	Corrosion	1.64	Galvanic corrosion	0.38	Scale	11.97	Non aggressive	0.49	Non corrosive
S24	-2.06	Corrosion	11.77	Corrosion	11.07	Corrosion	2.59	Galvanic corrosion	0.36	Scale	12.03	Non aggressive	0.47	Non corrosive
S25	-2.13	Corrosion	12.06	Corrosion	11.69	Corrosion	2.33	Galvanic corrosion	0.69	Scale	11.99	Non aggressive	0.91	Non corrosive
S26	-2.21	Corrosion	12.15	Corrosion	11.7	Corrosion	2.51	Galvanic corrosion	0.65	Scale	11.93	Non aggressive	0.86	Non corrosive
S27	-2.07	Corrosion	11.9	Corrosion	11.46	Corrosion	2.58	Galvanic corrosion	0.75	Scale	11.96	Non aggressive	0.98	Non corrosive
S28	-2.88	Corrosion	13.41	Corrosion	12.81	Corrosion	1.69	Galvanic corrosion	0.31	Scale	12.08	Non aggressive	0.4	Non corrosive
S29	-2.83	Corrosion	13.35	Corrosion	12.79	Corrosion	1.63	Galvanic corrosion	0.32	Scale	12.1	Non aggressive	0.41	Non corrosive
S30	-3.17	Corrosion	13.98	Corrosion	14.01	Corrosion	2.31	Galvanic corrosion	2.58	High corrosion	11.91	Non aggressive	3.38	Corrosive
S31	-2.56	Corrosion	13.16	Corrosion	13.67	Corrosion	2.41	Galvanic corrosion	2.63	High corrosion	12.3	Non aggressive	3.45	Corrosive
S32	-2.61	Corrosion	13.26	Corrosion	13.74	Corrosion	2.11	Galvanic corrosion	2.73	High corrosion	12.3	Non aggressive	3.56	Corrosive
S33	-2.51	Corrosion	13.05	Corrosion	13.58	Corrosion	1.98	Galvanic corrosion	3.01	High corrosion	12.3	Non aggressive	3.91	Corrosive
S34	-2.69	Corrosion	13.17	Corrosion	13.46	Corrosion	2.1	Galvanic corrosion	2.41	High corrosion	12.09	Non aggressive	3.14	Corrosive
S35	-3.94	Corrosion	14.72	Corrosion	14.05	Corrosion	2.04	Galvanic corrosion	2.43	High corrosion	11.1	Non aggressive	3.16	Corrosive
S36	-1.89	Corrosion	11.68	Corrosion	11.3	Corrosion	2.51	Galvanic corrosion	0.51	Scale	12.19	Non aggressive	0.67	Non corrosive
S37	-2.91	Corrosion	12.71	Corrosion	11.33	Corrosion	1.84	Galvanic corrosion	0.51	Scale	11.2	Non aggressive	0.66	Non corrosive

Larson skold Index (LI)

Based on the Larson Skold Index (LI), the water samples exhibited varying tendencies toward scale formation and corrosion across the study locations. Samples from Kumuli (S1 to S5), Gudalur (S6 to S9), Cumbum (S10 to S12), Bodimettu (S21 to S27), Allinagaram (S28 and S29) and Melmangalam (S36 to S37) were classified as scale forming but non-corrosive. Samples S15 to S20 and S30 to S35 from Thevaram and Aundipatty showed high corrosion potential due to high concentrations of chloride and sulphate, whereas samples S13 and S14 from Uthamapalayam demonstrated a corrosive nature. Depending on the local water chemistry, the Larson Skold index values varied from 0.26 to 3.80, with an average of 1.37, indicating a shift from scale-forming to moderately and highly corrosive conditions.

Aggressiveness Index (AI)

The majority of samples (S1 to S14, S16 to S18, S21, S24, S28, S29, S31 to S34, and S36) fell into the non-aggressive category according to the Aggressiveness Index (AI) assessment. S15, S19, S20, S22, S23, S25 to S27, S30, S35, and S37, on the other hand, were categorised as somewhat hostile. With an average of 12.11, the AI scores ranged from 11.10 to 12.57, indicating moderate aggressiveness of collected water samples.

Corrosivity Ratio (CR)

The Corrosivity Ratio (CR) analysis showed significant variation in water corrosiveness across the study sites. Samples with CR values below 1**,** indicating non-corrosive water**,** were recorded at S1 to S9, S11 to S12, S21 to S29, and S36 to S37**,** corresponding to Kumuli, Gudalur, Cumbum, Bodi-mettu, Allinagaram, and Melmangalam**.** Samples with CR values above 1**,** reflecting corrosive conditions**,** were found in Uthamapalayam, Thevaram, and Aundipatty (S13 to S20, S30 to S35). The highest CR values were observed in Thevaram and Aundipatty**,** indicating strong corro-sion potential**,** likely due to high concentrations of aggressive ions. Results showing close agreement with the results obtained from Larson skold index. These results reveal spatial differences in corrosion risk**,** emphasizing the need for site-specific water treatment and corrosion mitigation measures. The summary statistics of calculated corrosion indices were tabulated (Table 3).

In the present study, LSI, RSI, PSI, and PPGC indicated that all samples were corrosive**,** while the Larson Skold Index and Corrosivity Ratio showed a range of scaling and corrosion potential of water, this divergence in classification reflects differences in the theoretical foundations, parameter sensitivity, and computational frameworks of the individual indices. In addition, the scaling and corrosion potential of water is influenced by factors such as pH, temperature, calcium hardness, alkalinity, and total dissolved solids (TDS)thus, changes in any of these parameters can significantly impact water stability [24].

CONCLUSION

The LSI, RSI, PSI, and PPGC analyses of 37 groundwater samples from nine locations across five taluks in Theni District revealed that the water is primarily corrosive, whereas Larson Skold, Aggressiveness Index, and Corrosivity Ratio revealed a range of scale-forming to moderately corrosive conditions. The observed variance in corrosion potential is due to pH, alkalinity, calcium hardness, and large concentrations of hostile ions (sulphate and chloride). High levels of sulphate and chloride, which accelerate localised and galvanic corrosion, represent a serious threat to metallic distribution infrastructure. The study recommended that is to extend the life of the system by adopting nonmetallic pipes such as PVC or corrosion-resistant alloys. The majority of the water quality parameters in the samples from Kumuli, Gudalur, and Cumbum met acceptable standards, according to the spatial distribution map of the parameters; however, iron concentrations were higher than recommended levels, suggesting a potential for corrosion. In contrast, groundwater samples from Uthamapalayam, Allinagaram, Thevaram, and Aundipatty surpassed recommended limits, signifying aggressive and corrosive water conditions**.** Conversely, samples from Melmangalam and Bodimettu remained within acceptable limits for all parameters, suggesting reduced vulnerability to contamination and corrosion processes. However, these areas require preventive measures to protect the water from future contamination and corrosion. These findings demonstrate the necessity of specific water treatment and material selection to prevent corrosion and ensure the long-term integrity of the water distribution network in the Theni District..

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IZVOD

KOROZIVNOST PODZEMNIH VODA I NJENE IMPLIKACIJE NA DEGRADACIJU MATERIJALA U SISTEMIMA DISTRIBUCIJE VODE

Kompletna studija kvaliteta podzemnih voda i potencijala korozije sprovedena je u okrugu Teni, Tamil Nadu, koristeći 37 uzoraka vode prikupljenih sa devet lokacija između marta i aprila 2025. godine. 23 fizičko-hemijska parametra i 4 metalna jona analizirana su prema standardnoj proceduri. Tendencija vode ka stvaranju kamenca i korozivnosti analizirana je pomoću sedam indeksa korozije, uključujući Langelijerov indeks zasićenja (LSI), Riznarov indeks stabilnosti (RSI), Pukorijusov indeks stvaranja kamenca (PSI), potencijal za podsticanje galvanske korozije (PPGC), Larsonov indeks Skolda (LI), indeks agresivnosti (AI) i odnos korozivnosti (CR). Rezultati su pokazali da LSI, PSI, RSI i PPGC dosledno ukazuju na korozivnu vodu, dok su preostali indeksi odražavali raspon od stvaranja kamenca do umerene korozije, ilustrujući prostornu varijabilnost pH vrednosti, alkalnosti, koncentracija hlorida i sulfata. GIS studija fizičko-hemijskih parametara pokazala je da su uzorci iz Utamapalajama, Alinagarama, Tevarama i Aundipatija bili iznad granica, što ukazuje na korozivne uslove vode. Dok su nivoi cinka, bakra i olova bili u prihvatljivim granicama, nivoi gvožđa u Kumuliju, Gudaluru i Kumbumu prevazišli su kriterijume SZO, najverovatnije zbog korozije cevovoda u agresivnim uslovima podzemnih voda. Nemetalne cevi poput PVC-a ili materijali otporni na koroziju poput nerđajućeg čelika preporučuju se za produženje veka trajanja cevi. Rezultati uključuju kvantitativnu procenu rizika od korozije u okrugu Teni, kao i informacije o metodama prečišćavanja vode i zaštite infrastrukture.
Ključne reči: *Parametri kvaliteta vode, Indeksi korozivnosti, okrug Teni, GIS*

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