Chapter 2
Hydrochemical Investigation and Water Quality Mapping in and Around Pallikaranai Marshland Area in Chennai, India

S. Packialakshmi, K. Nagamani, and B. Anuradha

Abstract Wetlands perform a wide range of ecological functions. It acts as a natural flood barrier that traps and deliberately releases surface water, groundwater, and flood waters. The groundwater system is among the integral components of the wetland/swamp and ecosystem. Pallikaranai swamp land is a freshwater ecosystem situated in the southern region of Chennai, India is supportive of recharging the surrounding aquifers and is the important flood regulator for southern part of the Chennai region. Human interventions such as garbage dumping, sewage discharges, and unplanned urbanization activities have substantially damaged the wetland ecosystem, and the nature of the wetland has been destroyed. The current study investigates the prevailing groundwater quality in and around the wetland and highlights the vulnerable status of the wetland. In addition, the study used geospatial tools and methodologies to understand the regional variation in groundwater quality, which served as a guide for implementing management actions to improve the wetland and surrounding aquifer system.

Keywords GIS mapping · Water quality · Spatial variation of groundwater · Pallikaranai · Chennai

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P. Thambidurai, A. K. Dikshit (eds.), *Impacts of Urbanization on Hydrological Systems in India*, https://doi.org/10.1007/978-3-031-21618-3_2

1 Introduction

Freshwater scarcity has become an environmental and social challenge that requires immediate attention at the local, regional, national, and global levels. Groundwater resources are in great demand for household, agricultural, and industrial applications since surface water resources are not equally distributed and sensitive to anthropogenic pollution (Paul et al., 2019; Packialakshmi et al., 2011; Sonkamble et al., 2014; Thambidurai et al., 2019; Thambidurai, 2017). On average, 65 percent of available groundwater is consumed for drinking and domestic purposes, while 15% and 20% of groundwater has been utilized for industrial and agricultural purposes correspondingly (Salehi et al., 2018; Adimalla et al., 2019). Groundwater appropriateness, particularly for domestic uses, is mostly governed by its quality, which has grown increasingly essential in recent years. In many places, groundwater resources are very sensitive as they have been exploited by various anthropogenic causes such as farming activities, land-use conversions, cultivation methods, and industrial activities. A significant role contributed to the freshwater environment by the wetlands ecosystem. Understanding how wetlands function and characterizing and measuring their buffer role would aid authorities in maintaining such ecosystems(Patnaik & Srihari, 2004; Sridevi & Ramachandran, 2012).

1.1 Reviews on Investigation of Water Quality

Water quality indexing is one of the most efficient methodologies for disseminating knowledge and awareness of the water quality of any potential region. Verma et al. (2020) have explored the importance of conducting water quality investigation using water quality indexing (WQI) and Geographic Information System (GIS) approaches for the Bokaro district, India. The GIS-based water quality index maps for the study area reveal that the area's alarming water quality was greater in the pre-monsoon season when compared to the post-monsoon season. In the pre- and post-monsoon seasons, water quality mapping revealed that 50.98% and 45.10% of the samples were found to be in a bad category, making them unfit for drinking. The high WQI readings in various groundwater samples from the Bokaro district suggest that the water is unfit for direct consumption and requires long-term treatment before being used for drinking. Further, the study found that rock weathering, ion exchange mechanisms, and anthropogenic activities all influenced groundwater chemistry. The research calls for proper water resource management plans to address groundwater resource issues. Piyathilake et al. (2022) conducted a study for developing the water quality indexing to establish a relation between the incidence of chronic kidney ailment of indefinite etiology and intake water quality in the Uva Province (UP), Sri Lanka. The WQI has a substantial positive association with the spatial variation of chronic kidney ailment patients in the study region, implying that the status of water quality had a major impact on the occurrence of chronic kidney disorders, according to the statistical study. The authorities can use these spatial distribution water quality maps for groundwater quantity-quality assessment strategies in these regions. The method of water quality indexing is extensively utilized as one of the promising techniques to express the prevailing status of water quality in an area of concern to the common public and officials. Also, the method of indexing can be effectually utilized for assessing the suitability of water for its various uses.

Also, Chabuk et al. (2020) assessed the surface water quality of River Tigris by using the water quality indexing technique in the geospatial platform. Twelve parameters (TDS, EC, Ca, Na, Mg, Cl, HCO_3, K, SO_4, BOD, TH, and NO_3) were taken from fourteen stations in and around the river regions. The weighted arithmetic technique was employed to assess the overall water quality index. The method of interpolation (IDW) was adopted in ArcGIS to develop the probability or forecasting maps for the selected 12 parameters at the stations in and around the River Tigris during the year 2016 for dry and wet seasons. The methodology consists of three approaches: field dimensions, mapping processes using GIS, and calculations. The inverse distance weighted interpolation technique (IDW) was employed to create the interpolation maps for each parameter during the study of the river's dry and wet seasons. In this interpolation technique, the points closer to the likely spots will have a better outcome on the projected values than those placed farther away from those points. This process was adopted to deliver interpolation between the selected points within the values between lower and higher ranges for all the parameters. The prediction methodology was adopted for the seasons on the three stations within the study region among the observed and predicted values. The outcomes showed that prediction for all the selected parameters assumed the suitable values for the regression coefficient. Also, the status of prevailing water quality for the study region deteriorated especially in the downstream regions, during the dry and wet seasons, and evidently in the southern parts of Iraq.

The GIS and remote sensing technologies have essential roles to perform altogether with spatial and topographical features of the event and for monitoring the water resource. These techniques will offer influential and analytical gears for analyzing and demonstrating the habitual structure procedure and functions. Furthermore, testing with satellite imageries and checking with segment data will give an alternate and precise factor recognition technique. The selected water quality parameters were chosen to quantify temporal changes for the investigation period, and a replacement technique was suggested by Najme (2016). This replacement technique supported the parametric statistic model. The empirical equation predicted the variable's significance by considering the events' cause and effects. Generally, the parametric statistic is considered a constant when a curve is presumed as a linear function ($y = ax + b$). This constant parameter established the relation between the variable (i.e., rate of change in water quality) as a function of the time factor (x) and the slope of the equation (Webster, 1997). Henceforth, the values of every water quality variable for the study periods were plotted to obtain the best fit of the linear line. Then, the constant of parametric statistics was defined as a relentless value for every water quality variable, called the regression coefficient. Values of negative sign for each and every water quality variable infers that variable over time will reduce trend and contrariwise. During this study, geo-based statistical analysis was executed in two stages, namely, (a) structural analysis, which targets in labeling and modeling of a spatial building of regression coefficient for the selected water quality variables, employing a structural implement of variogram, and (b) the employment of this construction for a chosen study problem (i.e., for mapping every water quality parameters).

Further, a few geostatistical algorithms were examined, including simple, ordinary, probability, and disjunctive natured kriging (ESRI, 2008). The simplest model (i.e., exponential, spherical, or Gaussian) and the related parameters were also tested through the semi-variogram analysis. From variography analysis, spatial and temporal changes in the groundwater quality were derived for each and every variable. A regression approach integrated with the kriging technique was applied to develop the mapping for spatial and temporal variation of water quality parameters. The outcome exposed that most soluble ions of Na and Cl ions are in the greatest ranges compared to other ions. Except for Ca ions, most of the soluble ions, including EC and TDS, were exceeded the most permissible ranges for domestic and drinking purposes. Then parameters such as EC, Na, and SO_4 showed no restriction for farming activities which supported the projected regression coefficient, and soluble ions such as Ca, Na, and Cl and total anions, cations, and EC have significantly increased during the study period. Comparing the most soluble ions indicated that during the study period, the ranges of HCO_3 are in an increasing trend, while the contrary trend was identified for Ca and SO_4 ions. The regression coefficient for SAR and EC has a greater correlation with Na and Cl. The results identified the spatial and temporal variations of groundwater sodicity and salinity for the study region which are greatly influenced by soluble ions such as Na and Cl. Juniet et al. (2016) have worked on the wetlands providing numerous invaluable amenities for society like attenuating floods, recycling nutrients, and recharging water to the subsurface and as natural environs supporting several species and their ecosystem. Because of unplanned urbanization activities, the sole available natural recharging system of Pallikaranai marshland, labeled as a reserved and protected area, is under threat and constricted to 1/10 of its authentic areal extent due to anthropogenic-related stresses. Further, the existence of a dump yard and wastewater treatment facilities that functioned within the ecologically preserved region of wetlands created a potential threat to the diversified species population of this wetland. Also, Kaaviya and Devadas (2021) established distinct water resilience regions in Chennai, India. The approach contained a total of 15 essential parameters. The AHP was used to disperse weight to every parameter by applying a multi-criteria analysis technique. A pairwise decision matrix was used to determine the factors comparative significance and the consistency ratio. Five important ranges in the water resilience strengths were represented by combining all maps using a weighted overlay analysis technique. This study is unique in that it takes a holistic approach to water resilience, incorporating food, famine, efficiency, and adequacy of required infrastructure facilities.

As a novel perception of successful management of water resources and climate change scenarios, scholars and policymakers can excellently apply the research outcomes to maintain resilience. This decision-making tool determines how the system is exposed to water-related concerns and implements flexibility measures. The mapping of water resilience provides a model for a researcher to evaluate in what different ways assumptions about future climate or other variables affect decision-making. The AHP-related planning method has been developed as a decision-making tool for using resilience processes. Water quality monitoring is widely acknowledged as the important phase for gaining a better indulgent of the features of water polluting phenomenon and developing effective alleviation strategies. The physical, chemical, and biological constituents of water regulate its quality. Substances such as heavy metals, insecticides, petroleum, and fertilizers are all part of the chemical composition. Turbidity, color, and temperature are part of the physical composition, while plankton and pigments are part of the biological constituent. Said and Hussain (2019) mapped and monitored pollution levels inside the study region that runs through the entire region using advanced GeoEye-2 data by examining the relationship between water quality variables and the value of the image's spectral reflectance. A total of hundred samples were collected at arbitrary spots in the river region and examined in the laboratory for 12 WQPs, which were then categorized as organic or inorganic. The lighter color shades on the WQP maps appear to represent the lowermost levels of pollution in all WQPs at the Wazirabad site, while the darker tones appear to show significant pollutant concentrations along the river segment. The research, on the other hand, demonstrates how GeoEye-2 photos may be used to regulate and reduce pollution levels in water bodies, which could be useful for long-term surface water resource planning and management. The study noted that pollution levels on the temporal scale during the study period in all different seasons might be addressed in future studies, which help devise appropriate solutions for reviving the polluted river region.

Investigating groundwater status and the various risk assessment factors are crucial for assessing measures for preventing probably dangerous ecological health complications in any part of the world. Due to extensive groundwater pumping in recent years, especially during the summer months, the setback of groundwater movement has resulted in seawater incursion, especially in the agricultural regions located in the coastal zones, rendering water of shallow and deep wells unhealthy for farming activities and consumption. The hydrogeochemical analysis combined with geospatial techniques identifies the regions where water quality is adequate for drinking, agriculture, and industry. Geospatial tools are used to geographically characterize data sets to generate maps and make spatial data comparisons. The Arc GIS spatial analyzer is an essential tool for creating maps that facilitate the interpretation of primary and other data sets. The water quality of the research area is depicted by spatially distributed maps and analytically interpreted hydrochemical variables (Gnanachandrasamy et al., 2015).The results indicated that during the pre-monsoon season, the values of TH were higher when compared with the post-monsoon season. The values of Na and Cl ions in both pre- and post-monsoon seasons disclose the ranges that are exceeded drinking water norms. This may be due to the effect of saline water intrusion into the aquifers near to the coastal zone. The study argued that requirement of sustainable management practices is crucial in order to prevent these circumstances. It also requested that the new deep bore well be drilled regularly to ensure local supply. Henceforth, it is recommended to investigate the groundwater quality in a consistent manner and strategy to be controlled in a rigorous mode to avert a further worsening of water quality, specifically for the coastal cities.

One of the concerns of the twenty-first century is the degradation of water quality. An agent which causes contamination lowers the standards of water, making the water risky to drink and causing health problems. The measured water quality variables are interpolated using the inverse distance weighted method for predicting the water quality variables of surrounding points (Ram et al., 2021; Aouiti et al., 2021; Inson et al., 2021). A GIS-based best fit semi-variogram model integrated with the ordinary kriging method in the geospatial platform is used to prepare the thematic maps for the selected water quality variables (Bhunia et al., 2018). Khan et al. (2017) investigated groundwater quality by developing GIS-based quality indexing. Each parameter's geographically varying grids were changed by normalizing them to WHO standards before being merged into a GQI grid. A new GIS-based technique was used to compare the GQI grids to the land-use map. The findings show that the land-use pattern does not fully influence the geographical variability of groundwater quality in the region. This is most likely due to the heterogeneous nature of land-use classes, particularly communities and plantations. Mohan and Gandhimathi (2009) investigated the impact of Perungudi dumping site leachate on groundwater located on the Pallikaranai marshland. The Chennai Corporation delivers 1650 tonnes of municipal solid waste per day. The occurrence and availability of groundwater greatly depend on the changes in topography, subsurface geology, and the prevailing climate in the particular region. The position of the aquifer also determines its recharge rate and its susceptibility to pollution and overuse. Hydrogeological investigations require a thorough grasp of the physical structure of the aquifers in which groundwater resides and circulates (Kulkarni et al., 2000; Mohamed et al., 2018; Li et al., 2021; Malar et al., 2015). The availability of huge volumes of good-quality data is crucial for the reliability and validity of hydrogeological investigations. Also, Ghalib (2017) assessed the groundwater quality degradation in the aquifers of the shallow depth in the study region of Iraq's Wasit Governorate in the northeast. The appropriateness of groundwater for drinking purposes was assessed using physicochemical parameters such as important anion and cation concentrations, TDS, pH, and EC, which are compared with WHO and Iraqi criteria. Water availability and quality have always been essential factors in determining life quality. Water quality is inextricably tied to water use and economic development. With the swift increase of urban population and related developmental activities need for more freshwater, Chennai is among the worst affected in the aspect of water quality and quantity. The city's municipal solid waste (MSW) generation rate has increased rapidly as a result of population growth and rising affluence. During the last decade, daily waste creation has doubled (Malleshappa & Jayanthi, 2013).

2 Description of the Study Area

Pallikaranai marshland is a freshwater environment situated in part Chennai, India (Fig. 2.1 & Table 2.1). It has an area of 80 km^2 and is located near the Bay of Bengal, about 20 km south in the direction of the city center. The Pallikaranai marsh is Chennai city's only remaining wetland habitat and one of South India's few and last natural wetlands. The wetland has reduced significantly due to the dumping of toxic solid waste along the road, sewage discharge, and the development of houses, railway stations, and a new road that connects Old Mahabalipuram Road and Pallavaram. Wetlands and river bodies in Chennai are chosen areas for solid waste disposal and as an unloading bowl for both industrial and domestic effluents (Aravindkumar et al., 2014).

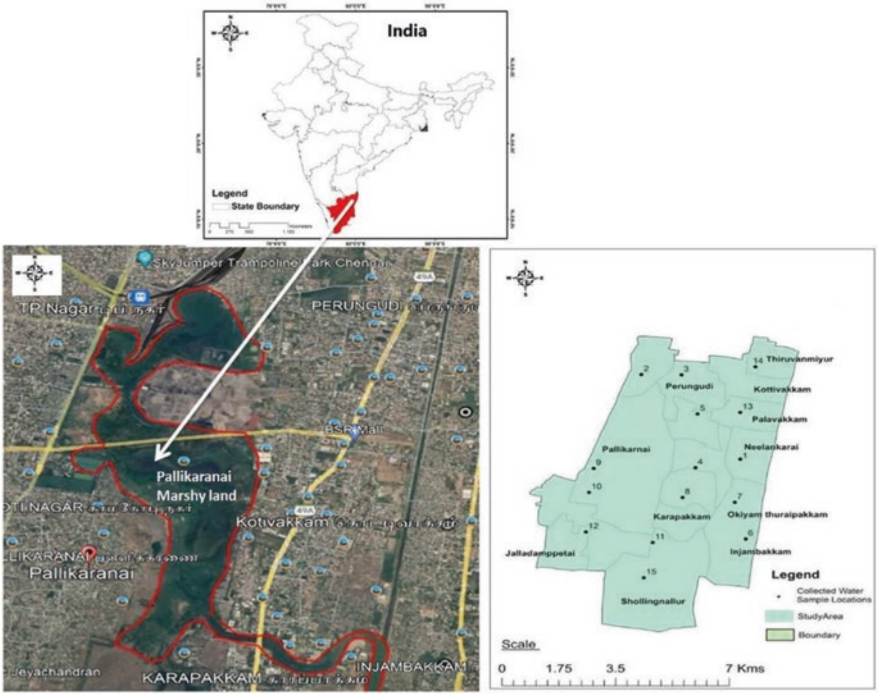


Fig. 2.1 Map of study area with its administrative boundaries

Table 2.1 Geographical characteristics of Pallikaranai marshland

Characteristics	Pallikaranai marshland
Geographical location	Located in between longitudes of 80.20° N and 80.23° N and latitudes of 12.92° E and 12.96° E
Areal extent	80 km^2
Catchment area	235 km^2
Surface elevation	3–7 m
Rainfall recharge	340 mm NE monsoon (November–January) and SW Monsoon (July–September)
Geology	Weathered rock – charnockite
Hydrology	Overflow from Velachery, tanks and hills in the western and south western direction find their way down channels, flooding the Pallikaranai marsh on a seasonal basis
Drainage	Surplus flow is released into Okkiyum Madavu and to Cooum, before finally reaching the Bay of Bengal via the Muttukkadu-Kovalam waterway

3 Material and Methods

The common method of garbage disposal in developing nations is to landfill municipal solid trash in an unlined dumping site. It pollutes natural and fragile land, air, and water resources, affecting the communities near the dumpsite. The major and most serious consequence for the residents was groundwater pollution. The people residing near the dumpsite for a longer period were unaware of the quality of water that had been poisoned owing to the dumping yard, which arose 20 years back because they had lived near the dumpsite for three to four generations.

Stream of solid waste generated by individuals, institutions, industries, and business centers is designated as municipal solid waste (MSW). When MSW is incorrectly disposed of, it harms the surrounding environment and human health. Groundwater contamination and related health hazards are among the most severe problems nowadays. Most Asian countries encounter municipal solid waste management challenges due to rapid expansion in solid waste creation and unscientific dumping practices. Water permeates through this solid waste, resulting in leachate, which is made up of rotting organic substances mixed with other harmful metals such as lead, iron, mercury, chromium, and zinc and is a principal source of groundwater contamination around the dumpsite. From the identified background understanding, sampling was conducted post-monsoon season (January 2021) to investigate prevailing groundwater quality. The parameters of pH, EC, TDS, salinity, Ca, Mg, Na, Cl, K, SO^4, HCO^3, and CO^3 were tested for analysis. These result values were compared with standard (BIS) limits. Spatial variation of hydrochemical parameters was plotted as thematic maps using Arc GIS 10.3 Software. The sampling locations were determined after a thorough field study and by discussing with stakeholders. Selecting sampling wells (shallow open wells) to undertake a water quality study is critical for mapping the groundwater quality. The sampling wells were chosen within an aerial coverage of approximately 3–5 km^2, and a

Table 2.2 List of sampling wells for analysis

Sl. no	Location	Latitude	Longitude	Water level below the ground level (ft)
1	Neelankarai	12.94556	80.25162	15
2	Taramani	12.97387	80.23537	40
3	Thoraipakkam	12.94269	80.23924	35
4	Perungudi	12.96073	80.23983	30
5	Akkarai	12.91878	80.25316	25
6	Injambakkam	12.93107	80.25015	20
7	Karapakkam	12.93269	80.23567	30
8	Narayanapuram	12.94246	80.21105	40
9	Pallikaranai	1293441	80.20978	35
10	Sholinganallur	12.91758	80.22743	40
11	Jalladianpettai	12.92113	80.20891	35
12	Palavakkam	12.96125	80.25163	40
13	Thiruvanmiyur	12.97656	80.25585	35

random sampling technique was used. Table 2.2 shows the list of sampling wells for conducting water quality investigation. Thirteen sampling points were selected and plotted using GPS for the accuracy of the location to conduct the investigation. The earlier finding (Packialakshmi et al., 2011; Packialakshmi & Ambujam, 2012; Parameswari & Mudgal, 2014, 2015; Ebong et al., 2017) suggested that concentration hydrochemical parameters such as Ca, Mg, Na, and Cl were exceeded during post-monsoon than in pre-monsoon season which may be due to dissolution rock minerals, dilution, and weathering effects.

4 Results and Discussions

Due to population increase, urbanization, and related industrial development, groundwater is being increasingly contaminated by the issues like alkalinity, acidity, heavy metals, and related noxiousness and microbes worldwide. Examining groundwater quality in the possible contamination zone and surrounding surface water is now critical to preparing for remedial procedures. The investigation of groundwater quality was carried out at Pallikaranai marsh area, Chennai, India, by examining its physicochemical features. The hydrochemical investigation was carried out in the Pallikaranai marshland area to identify the area affected by poor water quality and the source of salinity in this aquifer. The study area is completely surrounded by the charnockite hard rock aquifer on the western side and the coastal aquifer zone in the eastern direction. Residential and industrial developments, especially in the coastal zone, may have an impact of saline water ingression. The evaluation of hydrochemical values (Table 2.3) also suggests that samples taken near coastal zones are of very poor quality and groundwater in this sector is unfit for human consumption. It is apparent that the overextraction of groundwater sources

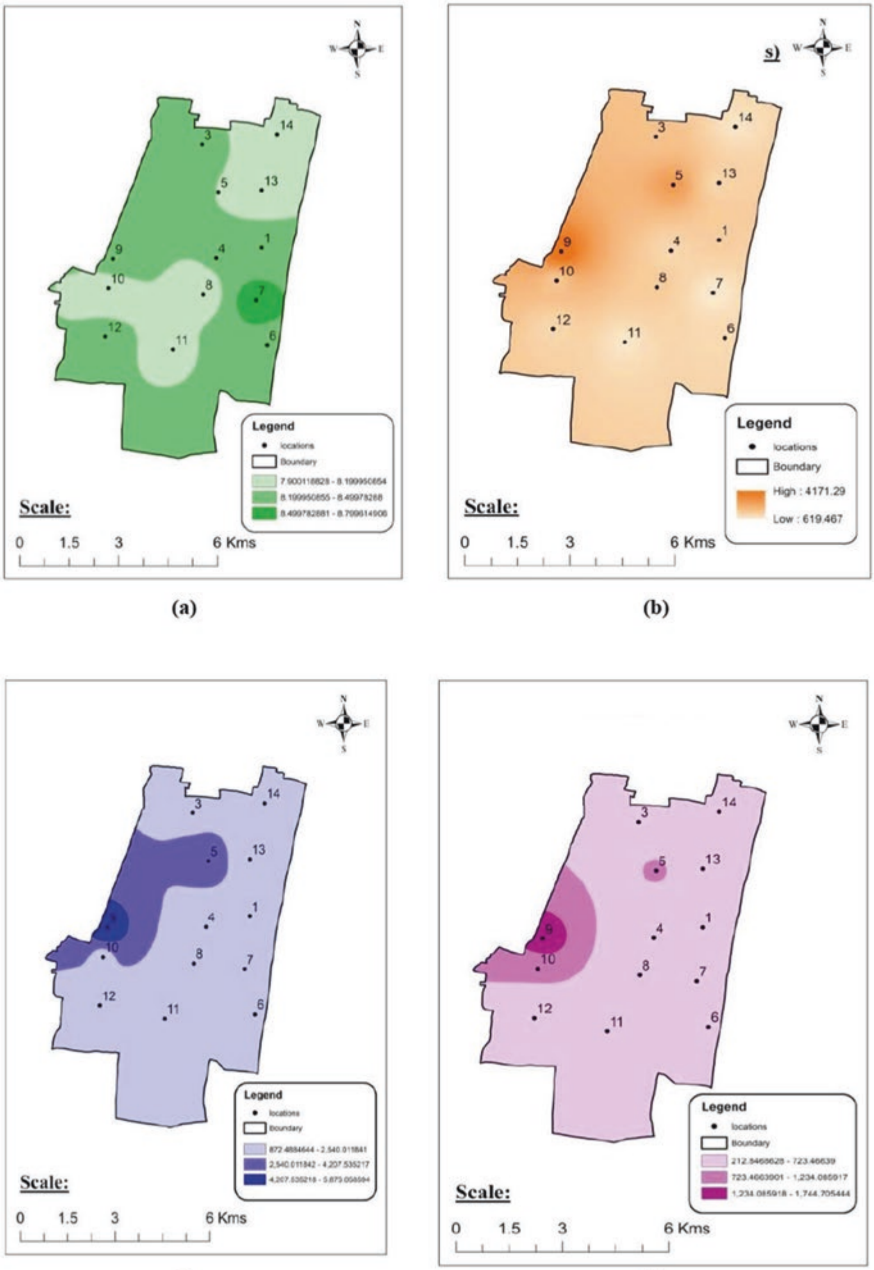
Table 2.3 hydrochemical parameters of selected sampling wells

S. no	pH	TDS	EC	Salinity	Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4
1.	8.24	1358	1912.68	600	144.15	105.60	50	28	382.86	0	505	141.91
2.	8.30	1616	2276.06	702	134.14	161.43	56	17	485.67	0	625	136.76
3.	8.21	1092	1538.03	545	84.09	65.12	108	37	33.23	0	310	155.88
4.	8.20	2591	3649.30	1920	250.26	137.12	388	38	786.12	100	750	241.18
5.	8.40	1050	1478.87	416	140.15	103.17	30	6	304.87	0	365	100.74
6.	8.80	619	871.83	211	108.11	49.77	23	7	212.70	0	130	88.97
7.	8.00	1401	1985.92	927	106.11	131.09	100	28	545.23	0	315	184.56
8.	8.40	4172	5876.06	2800	384.12	174.23	645	124	1745	0	555.23	545.23
9.	8.01	1498	2109.86	685	224.23	122.59	144	9	726.73	0	145	126.47
10.	8.14	763	1074.65	614	90.09	44.91	66	11	243.23	0	245	62.50
11.	8.25	1118	1574.65	463	152.16	81.32	50	3	287.15	0	475	69.12
12.	8.10	1170	1647.89	660	150.16	65.54	64	34	402.12	0	325	129.41
13.	7.90	808	1138.03	620	150.16	10.23	56	20	305.12	0	234	32.35

has a severe impact on the coastal sector. The dump is in a sea-level low land area with poor drainage characteristics and comprises a large expanse of marshy terrain that is continually damp and seasonally flooded. The daily dumping rate is currently around 2000 tonnes. The liner on this dumpsite is insufficient to prevent leachate from accessing the underlying and nearby groundwater environment. The most prominent influencing element for assessing the current status of wetland and its future concerns is the possible implications of leachate formation from dumpsites on groundwater quality. The findings revealed that the wetland region and its surroundings are precarious. Figures 2.2, 2.3, and 2.4 depict the regional fluctuation of hydrochemical parameters, indicating a higher level of contamination throughout the research.

The collected water samples have pH in the range of 7.90–8.80 with an average of 8.20. Well no. 7 shows high level of pH, whereas location numbers 8, 10, 11, 13, and 14 are in permissible range. Humans are exposed when the pH is excessive acidic; their eyes, skin, and mucous membranes may get irritated. Main sources of TDS in receiving waterways include farm and residential overspill, soil contamination leaching, and point and nonpoint causes of water pollution. According to WHO guidelines, the TDS levels in drinking water should be between 500 and 1500 mg/l. The TDS levels in 50% of the samples collected exceeded the limits. High and protected quality deionized water is having a conductivity value of about 5.5 S/m, while regular water used for drinking purposes has a conductivity of 5–50 mS/m, and saline water has a conductivity of about 5 S/m (Table 2.4).

The regional variation of hydrochemical parameters in the research area is depicted in Figs. 2.2 and 2.3. Chloride increases both the electrical conductivity and the corrosive characteristics of water. Chloride concentrations above 250 mg/li can produce discernible taste in water; however, the related cations determine the threshold. Consumers, on the other hand, may acquire used to concentrations greater than 250 mg/l. Potassium is an electrolyte and a mineral. The K concentrations



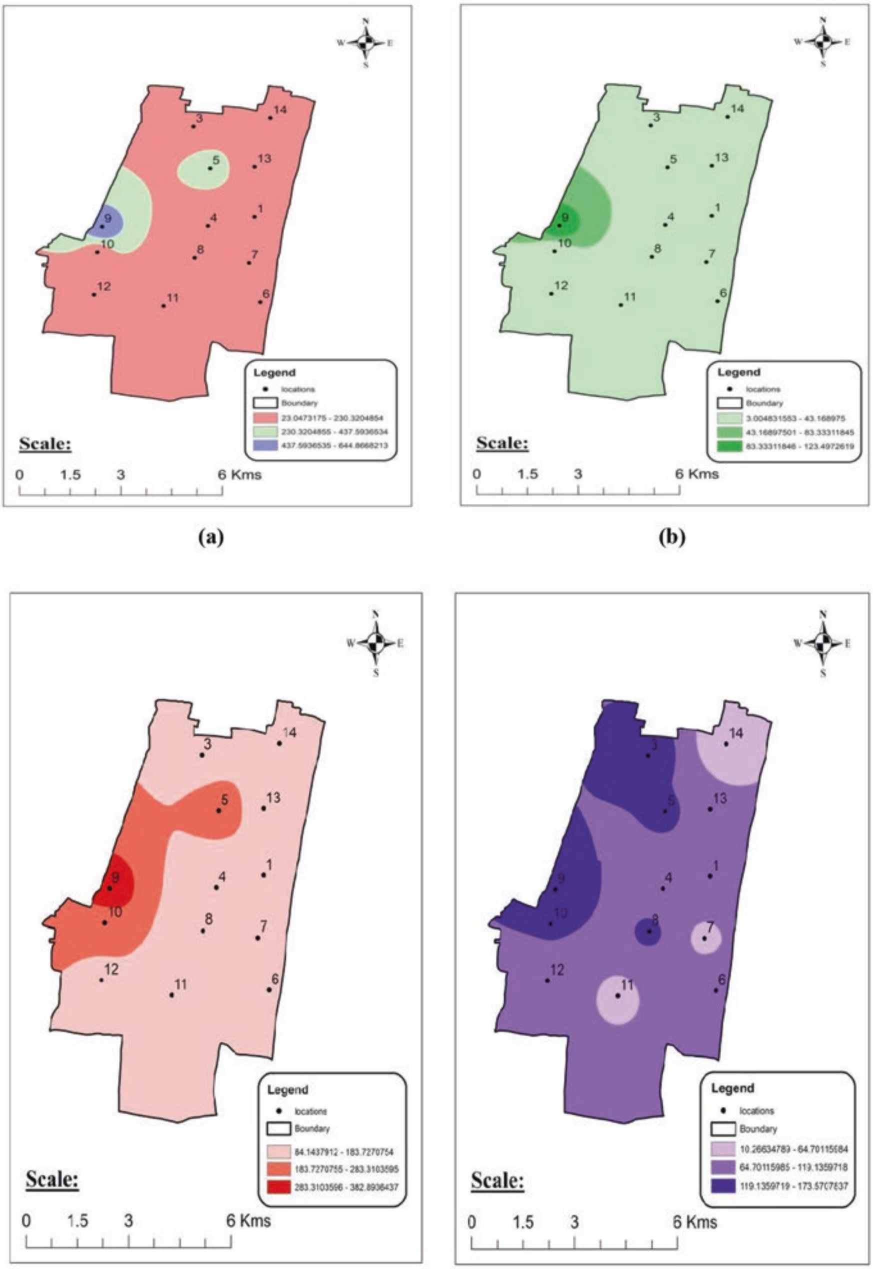
(a)

(b)

(c)

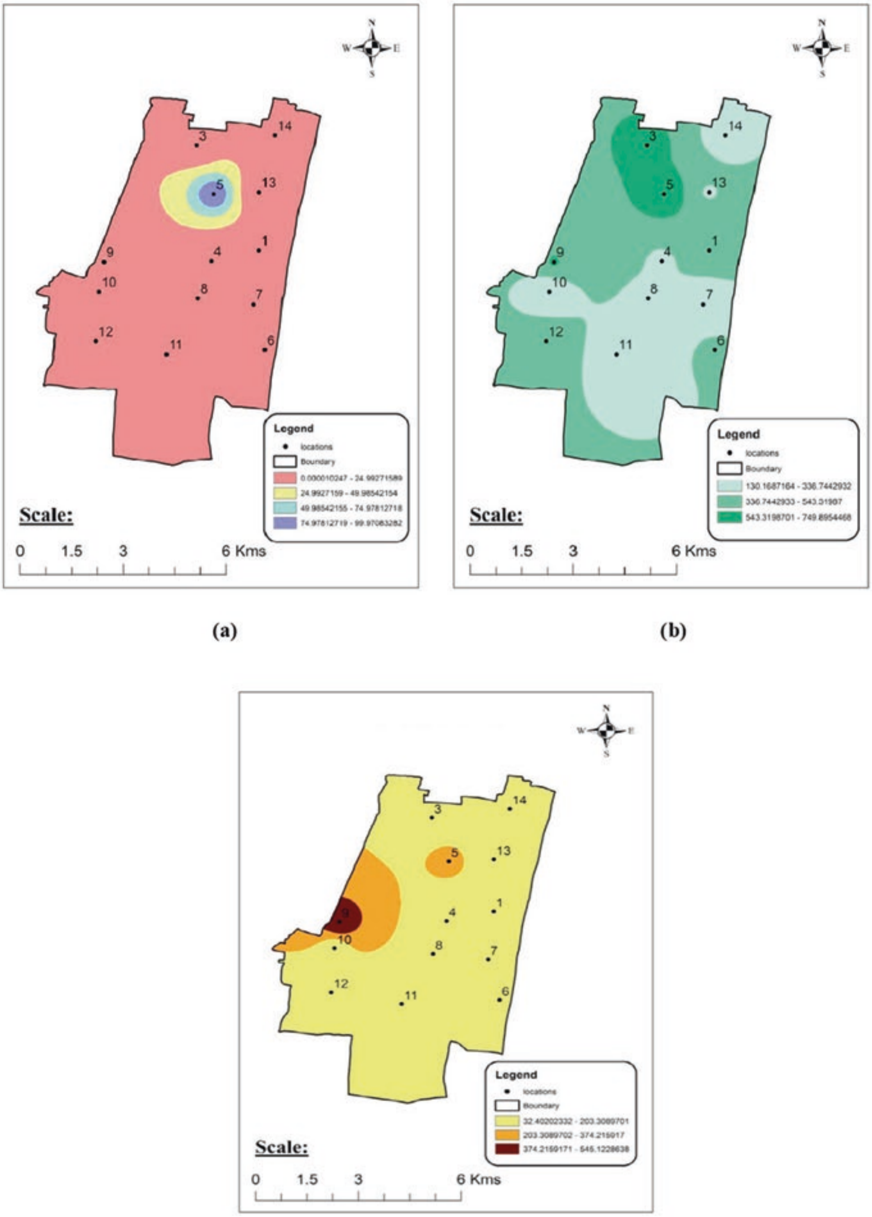
(d)

Fig. 2.2 Spatial variation of (**a**) pH, (**b**) TDS, (**c**) EC, and (**d**) Cl concentrations in the study area



(a) (b) (c) (d)

Fig. 2.3 Spatial variation of (**a**) Na, (**b**) K, (**c**) Ca, and (**d**) Mg concentrations in the study area



(a)

(b)

(c)

Fig. 2.4 Spatial variation of (**a**) CO_3, (**b**) HCO_3, and (**c**) SO_4 concentrations in the study area

Table 2.4 Standards of drinking water as per World Health Organization (WHO) guidelines

Parameters	Range
pH	6.5–8.5
EC	500–1500 µs/cm
TDS	500–1500 mg/l
Ca^2+	70–200 mg/l
Mg^2+	50–150 mg/l
Na+	≤200 mg/l
κ+	≤12 mg/l
NH4+	≤0.5 mg/l
NO3 −	≤50 mg/l
Cl−	≤250 mg/l
SO4	≤500 mg/l
HCO3	≤400 mg/l

measured ranges from 3 to 124 mg/l, with an average value of 27.14 mg/l. Carbonates are a function or relation of pH, temperature, dissolved carbon dioxide, cations, and other dissolved salts in the natural fluids. Concentrations of above 1000 mg/L have been reported in low-calcium, low-magnesium waters and notably where carbon dioxide-releasing activities, namely, sulfate reduction, are taking place in the groundwater storage formations. Calcium and magnesium are dissolved in most solids and rocks but particularly in gypsum, dolomite, and limestone.

Scale formation in boilers, water heaters, and pipes, as well as the unpleasant curd in the presence of soap, are mostly caused by calcium and magnesium. The sampling wells in the research area's western section have higher TDS, EC, Na, Ca, Cl, Mg, K, and SO_4 values than the other locations, implying that polluted water has accumulated and stagnated from nearby dumping activities in the marshy area. The parameters of EC, K, Cl, and HCO_3 exceeded more than WHO standards in 90% of the samples. The concentration of EC, K, Cl, and HCO_3 ranges from 871 to 5876, 3 to 124, 33 to 1745 and 130 to 750 mg/l, respectively. The majority of the parameters exceeded many fold higher than WHO standards in the sampling wells positioned in the western and central regions of the study location.

The leachate has created elevated pollutant concentrations in the majority of the water parameters. This high concentration is most likely owing to contamination from the disposal site's leachates, which have filtered into the groundwater (Eldho, 2001; Mor et al., 2006). The considerable volume of harmful inorganic minerals that have leached out from the dumpsite accounts for the greater total dissolved solids values. A high chemical oxygen demand indicates the presence of organic stuff. In most of the samples, the amount of chlorides is found to be higher than acceptable levels, irrespective of the seasons. The previous study conducted by Vasanthi et al. (2008) stated that in the majority of the areas in the Pallikaranai surroundings, total hardness is between 250 and 5800 mg/l, above the acceptable ranges. At some sites, it is noted that amount of nitrates and sulfates is higher than standards. The main dominating anions and cations in the groundwater in and around the dumping yard located in the wetland area were Na > Mg > Ca > K and

$Cl > HCO_3 > SO_4 > NO_3$. The Marshland's hydrogeological formations cause ions such as Na, HCO_3, Cl, and K to accumulate, potentially dominating groundwater chemistry and importing salinity and hardness, rendering the water unfit for potable use.

5 Conclusions

The present study investigated the prevailing status of hydrochemistry of groundwater aquifers in and around Pallikaranai marshland. This study aims to determine the likely concentrations of major and most dominating ions in the groundwater over time as a result of ions or contaminants being discharged from landfill leachate into the underlying groundwater. The leachate formed by indiscriminate dumping of solid and liquid waste on the eco-sensitive wetland region has a significant impact on groundwater quality in that location, according to the field survey and stakeholder debate. According to the hydrochemical investigation, the current groundwater quality is saline, and higher EC values reflect a greater ionic strength than WHO limits. The majority of the parameters exceeded WHO standards in the sampling wells located in the western and central portions of the study region. The Marshland's hydrogeological formations cause ions such as Na, HCO_3, Cl, and K to accumulate, potentially dominating groundwater chemistry and importing salinity and hardness, rendering the water unfit for potable consumption. According to the study, municipal solid waste disposal is a complicated element progressively disturbing natural and human ecosystems. Developing improved management approaches will pave the way to alleviate environmental and socioeconomic problems. The studies conducted by several researchers have also confirmed that identified groundwater quality parameters in the study area exceeded the acceptable level and showed that groundwater available in that study region is not protected and safe for the usage of any purposes such as drinking, domestic, agricultural, aquatic life, and industrial uses. Further, the results suggested that regions affected due to the anthropogenic sources of contamination need to be protected. It urges the need for innovative treatment options to revamp the system for the sustenance of the vulnerable wetland ecosystem. Hence the study recommends continual research on heavy metal accumulation, which threatens human health and livelihoods and affects the entire wetland ecosystem. The present investigation strongly advised that further study should be carried out on cost-effective, bio-based options to restore the functions and services offered by this vulnerable urban wetland system.

Acknowledgments The authors would like to thank the Sathyabama Institute of Science and Technology for providing the necessary support and laboratory facilities for conducting filed work and utilizing g GIS facilities to carry out this research. The authors are grateful to the editors and anonymous reviewers for their valuable suggestions and inputs.

Declarations **Conflict of interest:** The authors declare that they have no conflict of interest.

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