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Research Article

Ground and surface water quality assessment of Palladam Taluk using Geographical Information System and Modified National Sanitation Foundation -Water Quality Index

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Abstract
In this work, the assessment of surface and ground water quality of Palladam Taluk, Tiruppur, district, Tamil Nadu, India were carried out using Geographical Information System (GIS) and Modified National Sanitation Foundation -Water Quality Index (MNSF-WQI). Four samples from surface and twenty seven samples from ground water sources were taken from Palladam Taluk, Tiruppur District. In the current study, the surface and ground water samples were analysed for temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), biological oxygen demand (BOD), turbidity, total dissolved solids (TDS), total hardness (TH), faecal coliforms (FC), total phosphate (TP), total nitrate (TN), chlorides (Cl^-), sodium (Na^+) and fluoride (F^-) ions to investigate the suitability of surface and ground water for drinking and agricultural purposes through Geographic information system (GIS) and modified national sanitation foundation water quality index (MNSF-WQI) technique. The concentrations of TH, TDS, Cl^- and Na^+ were observed to be above the desirable limit of World Health Organization (WHO) guidelines and Bureau of Indian Standards (BIS). whereas F, BOD, DO, EC, TP, TN, FC and temperature were within the acceptable limits. The GIS-based WQI map analysis indicated that 45% of the study area having good water quality index and the remaining area showed medium quality water. Dyeing and textile industries in the study area are responsible for deteriorating the quality to medium quality of water which was not appropriate for direct utilization and needed prior treatment. There is no detailed report on assessment of the surface and ground water qualty of Palladam Taluk in Tamil Nadu using GIS and MNSF-WQI techniques.

Keywords: GIS, MNSF-WQI, Palladam Taluk, Physico-chemical parameters, Water Quality

INTRODUCTION

Over the last few decades, there has been an increasing need to conserve natural resources, particularly water which is the most important substance and is used equally by all realms of life (Mohammad and Saminu, 2012). Our environmental systems have been severely impacted by human activities, degrading water quality and water availability. Potable water comes from surface and groundwater, which is free from contaminants and microbes. Most of the diseases are directly related to poor drinking water quality and unhygienic conditions (World Health Organization, 2017). Inadequate control of hazardous effluents and disposal methods from the industries leads to the contamination of surface as well groundwater. Nowadays, the availability of good quality water has become a point of interrogation. There is an increasing concern about the availability and quality of water worldwide, and it is estimated that the demand for water will increase by 20-30% by 2050 (Wada *et al*., 2016). In Tamil Nadu, water demand is growing rapidly due to population growth and also due to higher per capita needs triggered by economic growth. There are 17 major river basins in Tamil Nadu, where Kaveri is the only largest river basin and Amaravati River is the longest tributary of the Kaveri River. The Amaravati River is the primary source of water for an irrigation, domestic water supply and industrial use in the districts of Karur and Tirupur. The rapid growth in population, the progress of industrialization, agrochemicals, and the dumping of urban and industrial waste have all played a key role in groundwater pollution and increased enormously the pressure on water resources (Chandra *et al*., 2015). Once the water is contaminated, its quality cannot be reestablished by preventing the pollutants from the source, and hence, it becomes very crucial to monitor the quality of groundwater frequently and to plan methods and means to safeguard it (Ramakrishnaiah *et al*., 2009). There are a number of water quality assessment methods, including a single factor, multi-index, fuzzy mathematics, grey system evaluation, artificial neural network, multi-criteria analysis, geographical interpolation and multivariate statistical approach (Dixon and Chiswell, 1996; Wang *et al*., 2016; Ji *et al*., 2016; Deng and Wang, 2017; Mladenović *et al*., 2018; Rakotondrabe *et al*., 2018; Chen *et al*., 2019).

The Water Quality Index (WQI) is one of the most effective tool for monitoring surface and groundwater pollution. The WQI provides a unique number which expresses the overall quality according to the various parameters. It summarizes large amounts of water quality data into simple terms, i.e., excellent, good, medium, bad etc (Pius and Jerome, 2011). The emergence of geospatial technologies such as the use of the Geographic Information System (GIS) enables rapid and cost-effective study and management of natural resources. Consequently, this technique has extensive applications, including the spatial distribution of groundwater quality parameters (Ganesh Babu and Sashikkumar, 2013; Ramakrishna *et al*., 2013). Therefore, many researchers (Vasanthavigar *et al*., 2010; Saleem *et al*., 2016; Boateng *et al*., 2016; Tiwari *et al*., 2018; Rawat and Singh, 2018) have successfully used this technique in groundwater studies, both for exploration and for quality mapping.

The aim of the present study was to investigate the ground and surface water quality of Palladam Taluk with the following objectives: i) to analyze physico-chemical parameters of the study area ii) to calculate NSF-WQI using nine water quality parameters, iii) to explore the water quality parameters by GIS technique, iv) to compare MNSF-WQI and NSF-WQI v) to determine the level of pollution and vi) to evaluate the safety of water for domestic purpose by comparing the results with the standards prescribed by World Health Organization (WHO).

MATERIALS AND METHODS

Study area

The sampling points chosen for the study were from the urban and rural area of Palladam Taluk, Tiruppur District. The latitude and its longitude of Palladam Taluk are 0.9909° N, 77.2858° E respectively. The total study area of the Sampling station was 7.32 Square feet were calculated using Arc GIS 10.8 software and location study area map is shown in Fig.1.

Thirty-one water samples were collected from different locations at one time during September, October and November month of 2019 and marked for the evaluation of physical and chemical attributes. 22 samples from handpump of depth from 106 m to 200 m, 5 from open well and 4 (S11, S13, S18 and S21) water samples from open source (lake). The water samples were filtered using a 4.5 μm Whatman filter paper to separate any suspended matter present. Total hardness, sodium, chloride, fluoride, electrical conductivity, turbidity, dissolved oxygen and biological oxygen demand were performed in the laboratory by American Public Health Association (APHA, 2017). Calcium (Ca), magnesium (Mg), and total hardness were evaluated by titrimetry (Deshmuk and Sainath, 2016), sodium (Na) was detected by Flame photometer (Elico -130). Electrical conductivity (EC) and turbidity was measured with the help of Conductivity meter (Elico-CM 180) and Turbidity meter (Elico-CL 52D), respectively. Dissolved oxygen (DO), biological oxygen demand (BOD) was carried out using Winkler's method. The concentration of fluoride and phosphate ions were analysed by UV-Vis Spectrophotometer (Shimadzu Model: UV-1800).

All the experiments for each sample were repeated thrice to attain quality assurance and control the quality. All the water quality parameters are expressed in mg/L except pH and turbidity. Each parameter was compared with the standards prescribed by WHO (2017) for drinking and public health purposes.

Water quality index (WQI)

WQI was used to evaluate the combined effect of individual water quality parameter on the overall quality of water (Mitra *et al*., 2006). NSF-WQI (Cristable *et al*., 2020; Zotou *et al*., 2020) was computed by using qi and Wi as shown below (eq (1))

$$WQI = \sum_{i=1}^{n} W_i \; q_i \qquad \text{-------------------------- (1)}$$

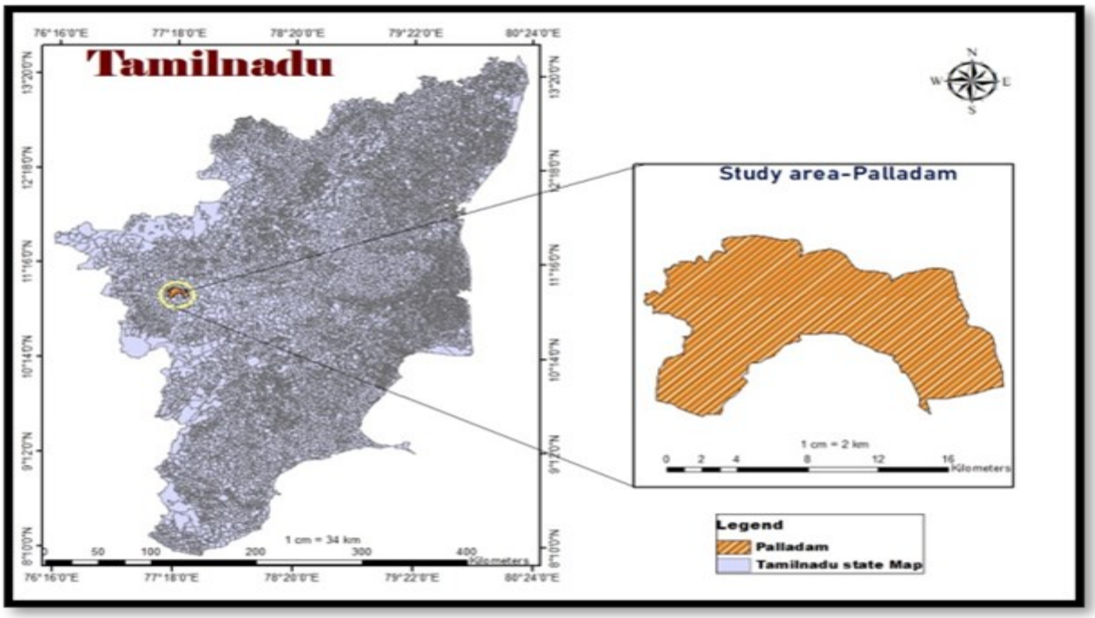

Fig. 1. *Study area map- Palladam Taluk.*

NSF-WQI = (0.17DO+0.16FC+0.11pH+0.11BOD+ 0.10Tem + 0.10TP+0.10 Nitrate+ 0.08TUR +0.07TDS) ……... (2)

The MNSF-Water Quality Index Formula was derived by altering NSF-WQI with seven water quality parameters. BOD must be calculated after incubation for 5 days. Since BOD calculation is a time-consuming process, the modified WQI formula without BOD and phosphate can be used to calculate the MNSF-WQI. For that, the weighing factor of BOD and TP was distributed to other seven parameters i.e Temperature, DO, FC, pH, TN, TUR and TDS by using mathematical principle of proportion and summation.

The resultant formula of MNSF-WQI was,

MNSF-WQI = 0.22DO + 0.20FC + 0.14pH + 0.13Tem+ 0.13 TN + 0.10TUR+0.09TDS --------- (3)

Spatial analysis using GIS

Spatial analysis of various physico-chemical parameters was performed using GIS contouring methods with Arc-GIS 10.8. Inverse-distance-weighted interpolation (IWI) techniques were used to prepare spatial distribution maps for each physicochemical parameter. The spatial distribution map of the pH, EC, TDS, TH, Na^+, Cl^-, F^-, BOD, DO and Temperature have been created for Palladam Taluk for ground and surface water quality index. GIS map helps us to understand the current status of ground and surface water in the study area.

RESULTS AND DISCUSSION

Spatial analysis of water quality parameters pH, TH, TDS, Cl, F, BOD, EC, DO, temperature and Na from the 31 water samples of Palladam Taluk are shown in Figs. 2 to 11 and the results are tabulated in Table 1. pH refers to the degree of acidity or alkalinity of water, is a crucial indicator that can be used to assess water quality and degree of contamination in water bodies (Ameen *et*., 2019). pH of the analysed water samples was found to be in the range from 7.5 to 9 indicating slightly alkaline nature due to the presence of carbonate and bicarbonate ions. Spatial analysis of pH value of the samples (Fig. 2) indicated that 28 samples were within the desirable limits (6.5-8.5) as per World Health Organization (2017) and Bureau of Indian Standards (2012) guidelines except for three sampling points S9, S15 and S18. TH in the water samples ranged from 153 mg/L to 2386 mg/L with an average value of 798 mg/L. The spatial map (Fig. 3) showed that 48.4% are >600 mg/L and 51.6% were greater than 600mg/L as per standard limits recommendation of WHO (2017) and BIS (2012). A high concentration of TH (2386 mg/L) beyond permissible limit was observed in Palladam Taluk, similar results were obtained (Arumugam and Elangovan, 2016) for Groundwater of Avinashi- Tirupur area (2560 mg/L). The value of TDS in the water samples was ranged from 72 mg/L to 4440 mg/L (average value 1697 mg/L). Spatial analysis of TDS concentrations of the water (Fig. 4) revealed that 16.2% of samples were within the adequate limit (500 mg/L), 25.8% samples were in acceptable (500-1500 mg/L) limit and 58% of the samples were above the permissible (>1500 mg/L) limit as per standard limit of WHO (2017) and BIS (2012). A higher TDS value reflects inorganic pollutants in surface and ground water samples (Ewaid *et al*., 2018). The Cl^- ion concentration in the study area was found to be in the range from 60 mg/L to 1540 mg/L and the average value was 637 mg/ L. The spatial analysis of Cl^- (Fig. 5) showed that

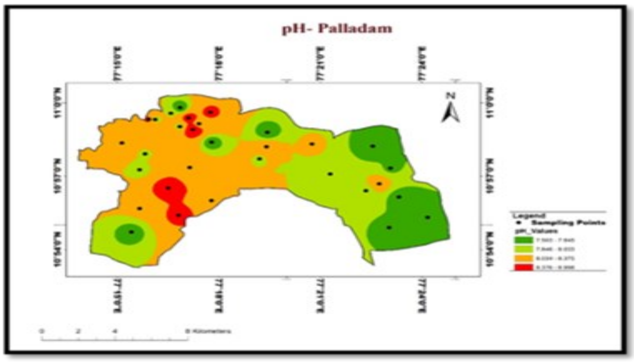

Fig. 2. *Spatial distribution of pH.*

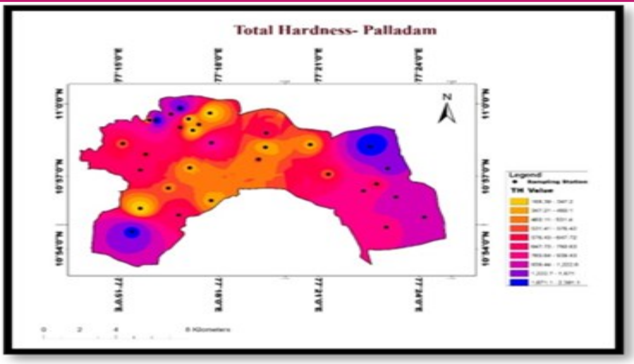

Fig. 3. *Spatial distribution of Total Hardness*.

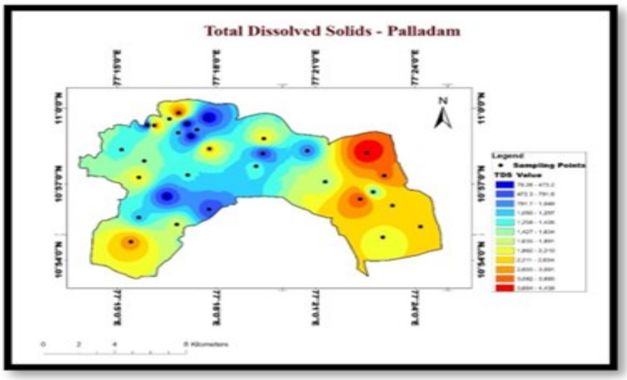

Fig. 4. *Spatial distribution of total dissolved solids (TDS).*

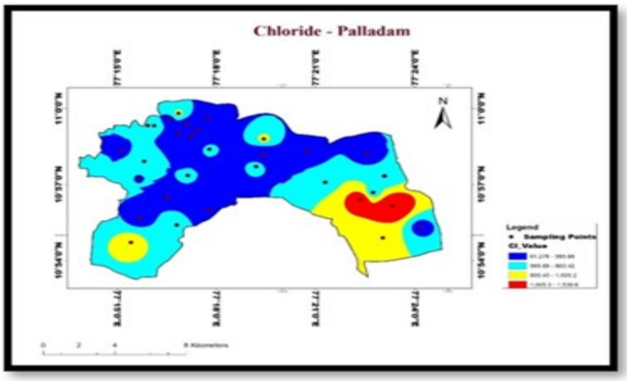

Fig. 5. *Spatial distribution of chloride.*

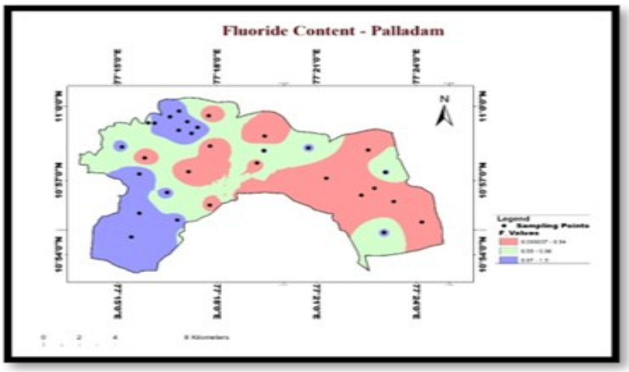

Fig. 6. *Spatial distribution of fluoride.*

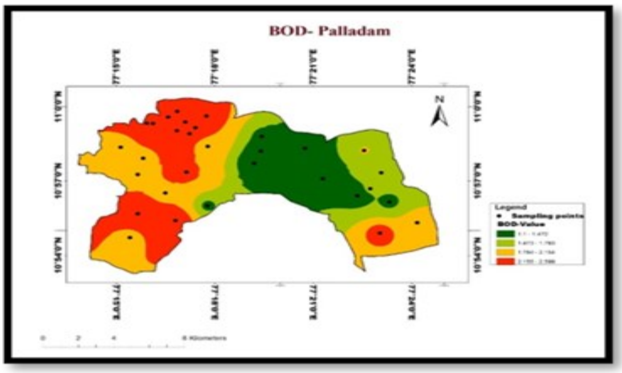

Fig. 7. *Spatial distribution of BOD.*

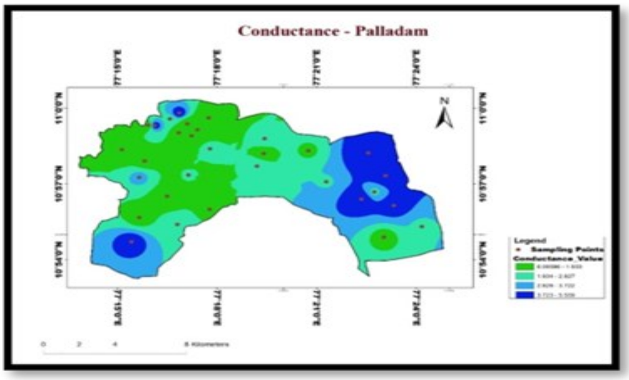

Fig. 8. *Spatial distribution of electrical conductivity.*

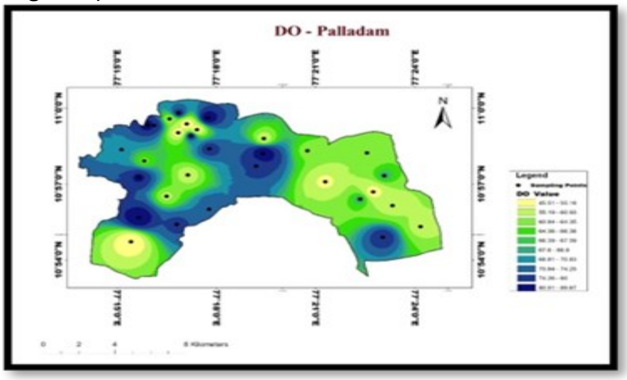

Fig. 9. *Spatial distribution of DO.*

93.5% of the water sample falls within permissible limit (<1000 mg/L) while 6.5% of the sample were above the permissible limit. Sources of fluoride are geogenic to groundwater, but an important contribution comes from industrial effluents. (Yadav *et al.*, 2015). F ion concentrations were ranged from 0 mg/L to 1.5 mg/L with an average value of 0.694 mg/L. BOD in the water samples of the study area varied from 1.1 to 2.6 with an average value of 1.95 mg/L. The spatial analysis of F^- (Fig. 6) and BOD (Fig. 7) in the water samples indicated

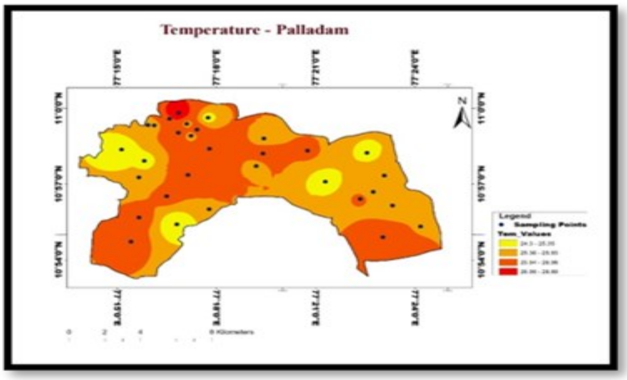

Fig. 10. *Spatial distribution of temperature.*

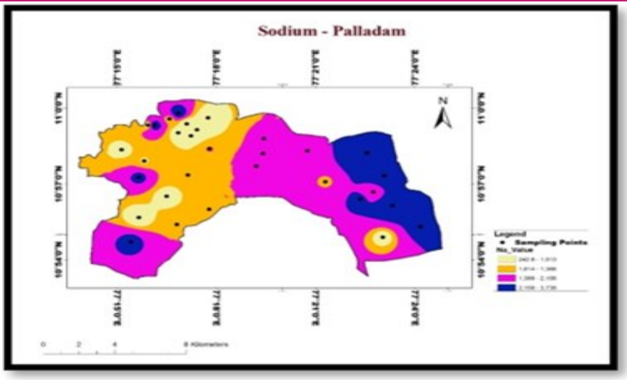

Fig. 11. *Spatial distribution of sodium.*

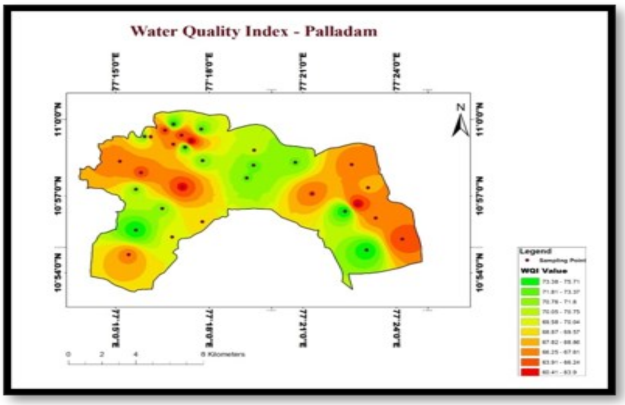

Fig. 12. *Spatial distribution of WQI.*

Fig.13. *WQI variation in Palladam taluk.*

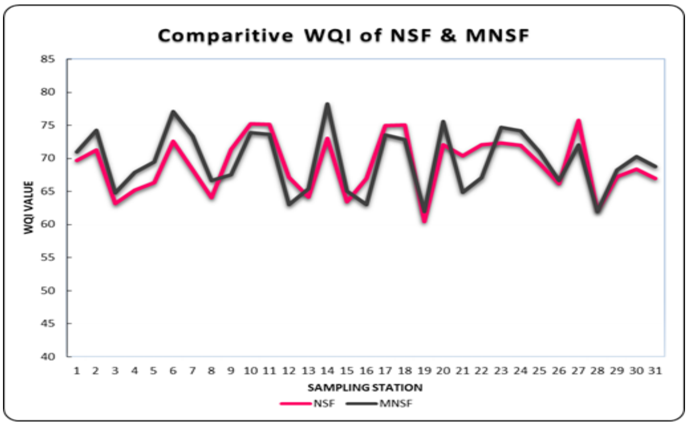

Fig. 14. *Comparison of the WQI values of NSF and MNSF.*

that all samples were within acceptable limits. The electric conductivity of the water is directly proportional to the concentration of dissolved matter in the water (Şener *et al*., 2017). EC value of the water samples ranged from 0.06 mS to 5.56 mS (Fig. 8). The results showed that all the water samples in the study area are within the desirable limit 300 mS. Dissolved oxygen is a vital parameter reflecting the quality of water. The values of WQI depending upon the value of DO in water. DO in the water samples of the study area were ranged from 45.5% to 89.7% with an average value of 67.5%. The spatial analysis of DO (Fig. 9) reveals that the sampling point (S15) have the lowest DO value (48.9) and S14 have the highest DO value (78.9). Temperature varied from 24.3°C to 28.9°C (average value 25.9° C). The spatial analysis of temperature (Fig. 10) of the samples was within the permissible limit recommended by WHO (2017) and BIS (2012). Na is a primary chemical in human body fluids and is not considered harmful at normal absorption levels from food sources and drinking water combined. The higher level of sodium affects the man via seizures and hypertension (Gnanachandrasamy *et al*., 2020). The amount of Na^+ ion in Palladam Taluk ranged from 240 mg/L to 3740 mg/L (avg. 1603 mg/L). The spatial analysis of Na^+ (Fig.11) indicated that all the water samples were above the permissible limit of WHO, 2017. According to the Table 1, it is clear that the concentrations of TP,

Table 1. Analysis of physico-chemical parameters in Palladam Taluk.

Place		Latitude	Longitude	DO %	FC MPN /100ml	pH	BOD mg/L	Tem ˚C	TP mg/L	TN mg/L	TUB NTU	TDS mg/L	TH mg/L	EC mS	Na mg/L	F mg/L	Cl mg/L
Pulliyappampalaiyam HP	S1	10.923	77.28	76.3	3	9	3	24	0.5	0	1	1770	692	2.56	1350	1	695
Venkatapuram HP	S2	10.954	77.261	82.3	6	8	2	26	0.8	0	1	2080	750	3.41	2510	1.5	590
Chittambalam HP	S3	10.956	77.286	56.3	2	8	2	27	1	2	1	1300	423	2.01	1260	0	630
Karadivavi HP	S4	10.965	77.264	63.5	5	8	2	25	1.5	1	1	1620	634	1.19	960	0	790
Panikkampatti HP	S5	10.973	77.252	69.5	4	8	2	24	1.5	1	1	1340	538	1.08	760	1	560
Kethanur HP	S6	10.989	77.266	85.6	3	9	2	25	1	1	1	72	153	0.06	630	0.5	630
Kusavampalayam HP	S7	10.989	77.269	79.5	3	8	3	26	1.5	1	1	3260	2386	5.15	3230	1.5	680
Palladam HP	S8	10.993	77.276	58.9	2	8	3	27	1	1	1	1710	1000	2.32	1100	1	520
Vadugapalaiyam HP	S9	10.942	77.275	59.6	2	9	2	26	0.1	0	1	310	519	0.99	620	1	560
Kethanur HP	S10	10.928	77.261	89.5	4	8	2	26	0.2	0	0	1160	192	1.16	510	1	490
Palladam OS	S11	10.997	77.281	78.9	6	8	2	29	0.3	0	0	3750	1923	5.26	3420	1	890
Kethanur OW	S12	10.912	77.257	45.5	4	8	2	26	0.3	0	0	2840	1825	4.72	2580	1.5	960
Madappur OS	S13	10.922	77.403	58.6	4	8	2	26	1	1	0	2210	1115	2.57	2510	0	490
Pachapalaiyam HP	S14	10.994	77.296	89.7	5	9	2	25	1	0	0	76	173	0.21	310	0	430
Kotapallayam OW	S15	10.99	77.285	45.5	4	9	2	26	1	0	0	79	192	0.23	240	1	480
Vadugapalaiyam OW	S16	10.984	77.281	48.9	4	8	3	27	0.1	0	0	1100	596	1.18	560	1	560
Kethanur HP	S17	10.915	77.384	78.9	5	8	2	27	0.2	0	0	1970	846	1.2	680	1	890
Vadugapalaiyam Pudur OS	S18	10.982	77.287	79.5	5	9	2	26	0.1	0	1	110	192	0.99	720	1.5	60
Vadugapalaiyam Pudur OW	S19	10.986	77.29	48.9	3	8	2	26	1	0	1	1080	480	1.08	590	1.5	520
Alattupalaiyam HP	S20	10.973	77.297	78.9	2	8	2	27	1	1	1	2450	980	2.55	1420	0	650
Madappur OS	S21	10.98	77.324	56.9	6	8	1	25	1.5	1	0	2210	673	2.53	1690	0	870
Pongallur HP	S22	10.972	77.346	63.2	3	8	1	26	1.5	1	0	887	423	1.67	1590	1	370
Nallakavundanpudur HP	S23	10.97	77.324	89.7	2	8	1	27	1	1	1	508	365	1.48	1450	1	270
Chinnakavundanpalaiyam HP	S24	10.962	77.32	75.6	2	8	1	26	1	1	0	1360	538	2.52	1970	0.5	670
Kottaimuttampalaiyam HP	S25	10.933	77.296	73.1	3	8	1	26	1	0	0	570	423	1.59	1360	0.5	270
Tottampatti HP	S26	10.952	77.355	53.1	3	8	1	25	1	0	1	1600	538	2.68	1250	0	740
Kondayampalaiyam BW	S27	10.94	77.373	68.9	2	8	1	26	0.2	0	0	3750	826	5.12	2310	0	1230
Kattur OW	S28	10.945	77.379	49.8	3	8	2	25	1	0	0	1290	634	2.47	1340	0	680
Sandamanayakkanpalaiyam HP	S29	10.936	77.389	57.9	2	8	1	25	1	0	0	2450	1192	4.65	3540	0.5	1540
Ammapalaiyam HP	S30	10.956	77.385	68.4	3	8	2	26	1	0	0	3260	1423	5.02	3520	1	589
Pongallur HP	S31	10.971	77.376	61.4	5	8	2	25	1	0	0	4440	2096	5.56	3740	0	450
WHO Standard Value (2017)				-	10	6.5-8.5	-	25-30	-	45	<5	<500	600	300	200	1.5	1000
BIS Standard Permissible limit (2012)				-	Not detected	6.5-8.5	-	25-30	-	-	<5	<500	600	-	-	1.5	1000

OS: Open source; HP: Handpump; BW:Borewell; DO: Dissolved Oxygen; FC: Fecal Coliform; BOD: Biological Oxygen Demand; Tem: Temperature; T.P: Total phosphate; TN: Total Nitrate; TUB: Turbidity; TDS: Total Dissolved Solids; TH Total Hardness; E.C.: Electrical conductance; Na: Sodium ion; F: Flouride ion; Cl: Chloride.

Table 2. Water quality level of Palladam Taluk.

Water Quality	Quality of the water	No. of samples
90-100	Excellent	0
70-89	Good	14
50-69	Medium	17
25-49	Bad	0
0-24	Very bad	0

TN, FC and TUR were within the desirable limits (World Health Organization, 2017). Faecal Coliform and temperature values of surface water were higher than groundwater. Surface water seemed to be slightly alkaline in nature when compared with groundwater.

Water Quality Index (WQI)

The WQI indicates the quality of water in relation to an index that reflects the overall status of water quality for consumption. The spatial distribution of the WQI of the current study area is depicted in Fig.12. WQI computed by incorporating the nine WQI parameters viz. temperature, pH, DO, BOD, TUR, TDS, FC, TP and TN into the GIS provided the quality of water, whether suitable or unsuitable for consumption. The GIS-based WQI map analysis (Fig.13) indicated that 55% of the study area showed a medium water quality index and the remaining area showed good quality water given in Table 2. Results indicated that water available from the study area (55%) is inappropriate for direct utilization and needs prior treatment. Treated water from dyeing and textile industries when discharged into water bodies it increases the temperature, alters pH, hence it disrupts the natural balance of aquatic life. Previously no study has been done on GIS based water quality index for the Palladam Taluk.

Water quality parameters based on the Modified NSF-Water Quality Index (MNSF-WQI)

The modified water quality index was derived by using seven water quality parameters instead of using nine parameters. The obtained results from NSF-WQI and MNSF-WQI are comparable. Fig.14 picturized the close relationship between the NSF and the Modified NSF formula.

Conclusion

In the present study, the assessment of the water quality of Palladam Taluk, Tiruppur district using MNSF-WQI and GIS mapping helped to understand and visualize the current status of ground and surface water in the study area. The assessment results showed that all the physicochemical parameters viz tem, pH, DO, EC, BOD, TUB, FC, TP, TN and F^- were within the desirable limit except Cl^-, Na ion, TH and TDS as per standard guidelines. The spatial distribution map showed that 45% of the study area fell under good water quality and 55% area medium water quality classes. Several dyeing and textile industries in the study area were responsible for the deterioration of the water to medium quality of water. The GIS based WQI map can be used to plan the future development programs for ground and surface water quality management of the study area of Palladam Taluk.

Conflict of interest

The authors declare that they have no conflict of interest.

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