



Assessment of Water Quality Using Modified Water Quality Index and Geographical Information System in Madathukulam Taluk, Tiruppur District, Tamil Nadu, India

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ABSTRACT

The present investigation is an extensive study of surface and ground water quality of Madathukulam taluk, Tiruppur District, Tamil Nadu, India, to estimate the quality of water using Modified Water Quality Index (MWQI) and Geographic Information System (GIS) technique. In this study 35 water samples from Open well, Bore well, River, Lake and Pond were analysed for the physicochemical parameters like pH, temperature, total phosphate, total nitrate, turbidity, total dissolved solids, dissolved oxygen, biological oxygen demand, faecal coliform, electrical conductivity, total hardness, chloride, fluoride, sodium and potassium. The resulting values were computed to investigate the quality of water using geographic information system and water quality index and compared with the standard drinking water guidelines proposed by the WHO (2017) and BIS (2012) for drinking and agricultural purpose. Inverse distance weighted (IDW) interpolation technique was used for preparing the spatial distribution maps for each physiochemical parameter. The analytical result signifies that 40% of the study areas are slightly acidic. GIS based water quality index shows that 63% of the area has recorded with good quality water, while the remaining 37% are of medium quality of water. The MWQI proved to be a useful method to classify the water similar to NSF-WQI in Madathukulam Taluk.

Keywords: Modified water quality index, Geographic information system, Madathukulam taluk, NSF-WQI, Correlation coefficient, World Health Organization.



INTRODUCTION

Due to boom in population, improper irrigation, fertilization, industries uncontrollable rise in heavy metal concentration, in past few decades, water bodies are polluted¹⁻². Safe drinking water is essential to humans and other life for safe metabolic activities and functioning of all organs of the body. For a healthy living, potable water is a vital. In order to get the safe potable water various methods are adopted to check the quality of drinking water. Natural processes and anthropogenic activities were responsible for the degradation of water quality throughout the world. Water resource management and contamination plays a vital role in water quality assessment. Water quality generally encompasses physical, chemical and biological parameters and can be assessed by using water quality index, GIS and statistical approach³. One of the commonly used tools for the quality of water is water quality index (WQI). WQI is one the powerful framework to explicit water quality which provides simple, stable, reproducible unit to measure and communicate data on the quality of the water to the concerned citizen and policy makers⁴. Geographical information system (GIS) is an effective tool for collection, storage, management and recovery of a spatial and non-spatial data utilised for spatial analysis. Using GIS interpolation groundwater quality map and spatial map for physico-chemical parameter are obtained and explained pictorially. Once the water is polluted the quality of the water cannot be regenerated hence it is to be monitored regularly.

The groundwater resources play an important role in meeting the ever increasing demands of the domestic, industry and agriculture sectors⁵. Like surface water, groundwater quality can be adversely affected as a result of anthropogenic activities that introduce pollutants into the environment. It can also be affected by natural processes that result in increased concentrations of certain constituents in the groundwater. Monitoring and assessing the quality of groundwater is significant for sustainable use of these resources⁶⁻⁷. A systematic study of correlation and regression coefficients of the water quality parameters not only helps to assess the overall water quality, but also to quantify relative concentration of various pollutants in water. This provides the necessary information

which may be used in water quality management programmes⁸⁻¹⁴.

For any city, for drinking and irrigation purposes a groundwater quality map is important and as preventive indication of potential environmental health problems. The present study has been carried out to assess the status of surface and ground water quality in and around Madathukulam Taluk, Tirupur district and to examine the changes in water quality that have happened during the last decade. Also the relation between various surface and ground water quality parameters has been derived by using correlation analysis. Correlation models based on observed water quality parameters provide general indication of the quality of pollution loads on relative magnitude of loads. This approach is also useful to detect changes in water quality constitutions within the system.

MATERIALS AND METHODS

Study Area

Madathukulam is a taluk belonging to the Tiruppur district in Tamilnadu state. It is located at the latitude of 10.5596° north and longitude of 77.3655° east and covers a total area of 451.23 square kilometres, which is measured by using ArcGIS 10.8 software is represented in Fig. 1. It is situated at the boundary of the Dindigul district. There are four town panchayats with thirty-five villages. The study area is primarily an agricultural based zone and there are six paper mills, one dyeing unit and one dairy unit. Amaravathi River runs through town of the Madathukulam Taluk. The major water resources for domestic, agriculture and industrial purposes are fulfilled by Amaravathi River, lakes, ponds, open well and bore well water.

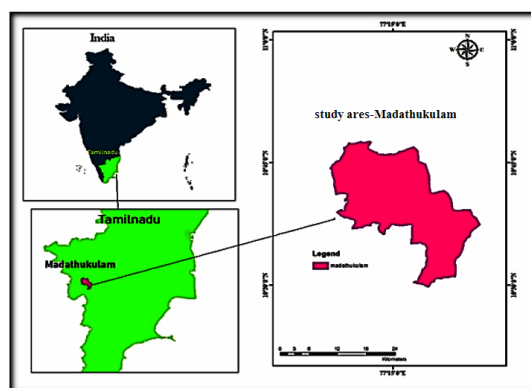


Fig. 1. Study area map-Madathukulam Taluk

Sampling and analytical procedure

For the assessment of surface and groundwater quality 8 samples from open well, 23 from bore well, 2 from river, 1 from lake and 1 from pond were collected in an acid-washed and pre-cleaned container during pre-monsoon (March-May) season of 2020 and labelled from S1 to S35. Physicochemical and biological analysis was performed for 15 parameters i.e as pH, Temperature ($^{\circ}\text{C}$), Faecal Coliform (MPN/100 mL), Dissolved Oxygen (%), Biological Oxygen Demand (mg/L), Total Dissolved Solids (mg/L), Total Phosphates (mg/L), Turbidity (NTU), Total Nitrates (mg/L), electric conductivity (mS), Total Hardness (mg/L), Chloride (mg/L), Calcium (mg/L), Magnesium (mg/L), Sodium (mg/L), Potassium (mg/L) and Fluoride (mg/L) using standard methods.

Temperature and total dissolved solids (TDS) were measured in the field during sampling using a sensitive thermometer (Digital thermometer DTM-902) and a TDS meter (Pocket TDS meter-Hanna) respectively for each sample and the other parameters are measured in the laboratory. Calcium, magnesium and total hardness were measured by titrimetric and sodium, potassium ion was detected by flame photometer (Elico-130). Turbidity was measured using turbidity meter (Elico-CL 52D). The Winkler's method was used for the determination of biological oxygen demand (BOD) and dissolved oxygen (DO). Fluoride and Phosphate ions were analysed using a UV-Visible Spectrophotometer (Shimadzu Model: UV-1800). Faecal Coliform is determined by membrane filtration. All the experiments were carried out thrice for each sample to attain quality assurance and control the quality. All the water quality parameters are stated in mg/L except Faecal coliform, pH and turbidity. All the water quality parameters and their analytical results are tabulated in Table 1 and compared with WHO¹⁵ and BIS standard values.

Water Quality Index (WQI)

The Water Quality Index is an effective tool and has been determined by the NSF-WQI method that is useful in recognizing the status of water bodies. Nine parameters were selected for the calculation of NSF-WQI is DO, FC, pH, BOD, Temp, TP, TN, TUR and TDS. The following steps were involved in the calculation of the WQI:

NSF-WQI was computed by using q_i and W_i as shown below:

$$\text{WQI} = \sum_{i=1}^n W_i q_i$$

Where, W_i -Weighing factor of parameter i

q_i -Water quality score of parameters i

n -Number of parameters

$$\text{NSF-WQI} = (0.17\text{DO} + 0.16\text{FC} + 0.11\text{pH} + 0.11\text{BOD} + 0.10\text{Temp} + 0.10\text{TP} + 0.10\text{TN} + 0.08\text{TUR} + 0.07\text{TDS})$$

The MNSF-WQI formula was derived by altering NSF-WQI with seven water quality parameters. For that, the weighing factor of BOD and total phosphate (TP) were distributed to other seven parameters. In the NSF formula, the contributing factor of BOD and total phosphates were distributed to the other parameters such as dissolved oxygen (DO), faecal coliforms (FC), pH, total nitrates (TN), turbidity (TUR), temperature (Temp) and total solids (TS) by using the mathematical principle of proportion and summation as follows.

The resultant formula of MNSF-WQI is

$$\text{MNSF-WQI} = 0.22\text{DO} + 0.20\text{FC} + 0.14\text{pH} + 0.13\text{Temp} + 0.13\text{TN} + 0.10\text{TUR} + 0.09\text{TDS}$$

Spatial analysis

The base map of Madathukulam Taluk was digitized using ArcGIS 10.8 software. The spatial distribution for water quality parameters pH, Temp, TP, TN, TUR, TDS, DO, BOD, FC, EC, TH, Cl^- , F^- , Na^+ and K^+ were done with the help of spatial analyst tool in ArcGIS 10.8 software given in Fig. 2-17. Inverse distance weighted (IDW) interpolation technique was used for preparing the spatial distribution maps for each physiochemical parameter and water quality index.

RESULT AND DISCUSSION

The physico-chemical and biological characteristics of the water samples in different places of Madathukulam Taluk are given in Table 1. The water quality index was calculated using the nine parameters and the overall water quality index values are given in Table 2. The analysed physio-chemical parameters were compared with water quality standards WHO¹⁵. Furthermore, statistical analysis of groundwater and

surface water samples beyond the drinking water limit are presented in the Table 3.

pH is an important parameter which indicates the hydrogen ion concentration in water¹⁶ and its scale is used to specify the acidic or alkaline nature of water¹⁷. The pH is altered by the presence of dissolved chemical compounds and biological processes in the water. If the water has less than seven may cause tuberculation and corrosion while higher the values may produce incrustation and complication during chlorination for water disinfection¹⁸. Spatial analysis of pH value of water samples (Fig. 2) ranged from 6.1 to 7.4 (avg. 6.68). The permissible limit of pH according to WHO is 6.5-8.5. 40% of the study areas are acidic, which signifies the acidic nature.

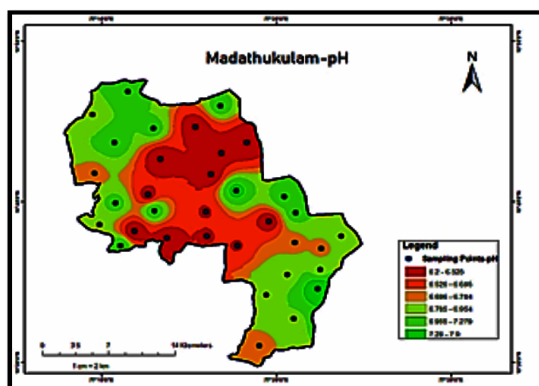


Fig. 2. Spatial distribution of pH

Dissolved oxygen is the water quality parameter which is vital for the respiration of aquatic life and the living organism¹⁹ which measures the amount of dissolved oxygen in the water, whose value impact on the living organism in the water bodies. Too high or too low DO can damage aquatic life and results in poor water quality²⁰. The reduction of oxygen is probably due to the influence of physico-chemical properties and it recommends the poor quality of water. Deficiency of DO gives bad odour to water due to anaerobic respiration of organic matter²¹ and low DO is an index of polluted water body²². The DO value of the analysed samples varied from 36.9% to 89.6% (avg. 64.6%). Spatial analysis of DO value of water samples (Fig. 3) indicates that samples collected from groundwater results with average DO value above 60% whereas samples from open source i.e from open well, lake, pond results in a lower DO. Low DO values are reported in open source sampling points S₈, S₁₆, S₂₄, S₂₇ and

S₃₅. Low DO value may lead to the degradation of an aquatic system.

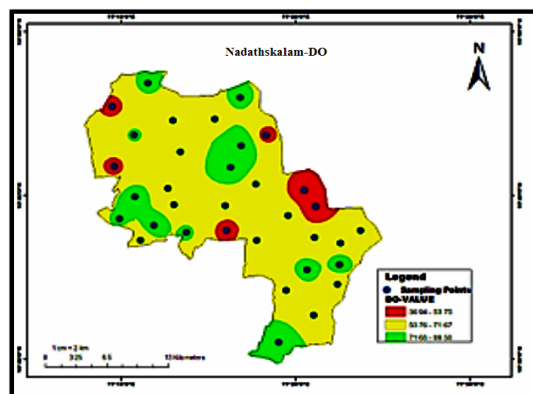


Fig. 3. Spatial distribution of DO

Biological oxygen demand is the amount of oxygen which is consumed by bacteria and fungi during the decomposition of organic matters under aerobic conditions for five days at a particular temperature²³⁻²⁴. BOD value is an indication of the amount of biodegradable waste in the water, as it utilizes organic matter in their respiration and eliminates oxygen from the water. Spatial analysis of biological oxygen demand (Fig. 4) ranges from 0.4 mg/L to 3.6 mg/L with an average value of 1.81 mg/L. The lowest value of BOD (0.4 mg/L) is found in sampling point S₆ and S₉, whereas the highest value of BOD (3.6 mg/L) is found in S₄. Faecal coliforms account for the total number of coliforms in the water, which corresponds to faecal contamination¹⁶. Faecal coliform values of the water samples ranged from 2 to 120 MPN/100 mL (avg. 21.9 MPN/100 mL). Spatial analysis of FC (Fig. 5) shows that sampling points S₈, S₁₀, S₁₆, S₂₄, S₂₇ and S₂₉ are above the permissible limits of WHO which are collected from open sources like open well, pond, and lake.

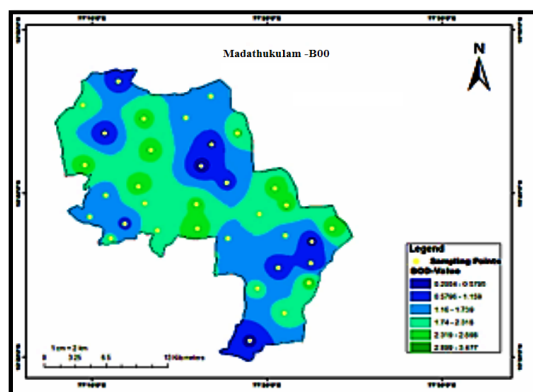


Fig. 4. Spatial distribution of BOD

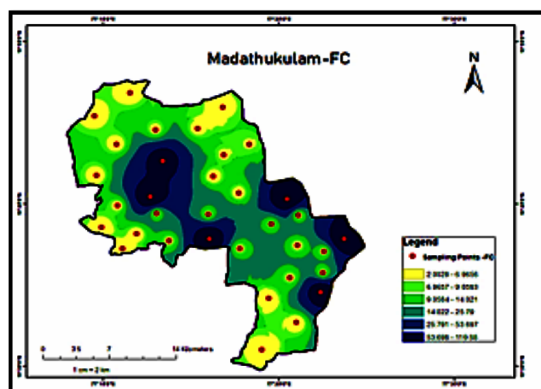


Fig. 5. Spatial distribution of FC

Temperature is one of the important physical parameters of water, since it controls various metabolic activities and life cycles. Temperature decides the rate of biochemical response in the aquatic ecosystem²⁵ and influences

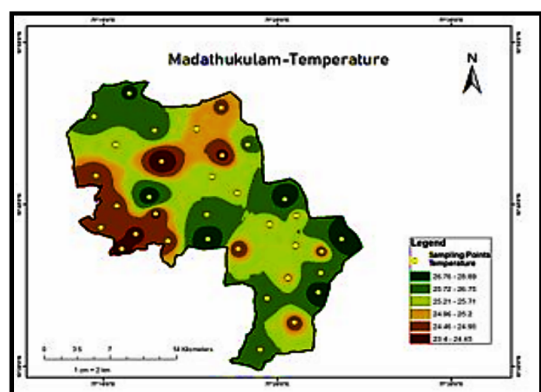


Fig. 6: Spatial distribution of temperature

High level of total nitrate in water can cause eutrophication of surface water and serious health hazards³⁰. Nitrate concentration increases due to anthropogenic activities, industry, domestic effluents etc. Spatial analysis of Total nitrate (Fig. 8) ranged from 0.1 mg/L and 3.6 mg/L with mean of 0.617 mg/L and is within the permissible limit of WHO¹⁵. Turbidity is an optical property of water, which causes the light to be scattered and absorbed rather than transmitted in straight lines, it is mainly caused by the presence of suspended matter clay, slit, finely divided organic and inorganic matter, plankton and other microscopic organism³¹. Turbid water will be coloured which affects the physical appearance of water³². High turbidity causes poor visibility and affects aquatic life³³. Spatial analysis map of turbidity (Fig. 9) ranged from 0 NTU to 1.5 NTU, with an average of 0.27 NTU and it does not exceed 5 NTU which is the desirable limit as recommended by WHO¹⁵. The highest turbidity is observed in S₂₄, S₂₉ of 1.5 NTU.

the rate of chemical and biological reaction²⁶. Spatial analysis of temperature (Fig. 6) ranges from 23.4°C to 28.9°C with an average value of 25.6°C. In the present study the lowest temperature 23.4°C was recorded in S₁₀ (Bore well) and the maximum temperature 28.9°C is observed in S₂₄ (lake). Total Phosphate is a key supplement for plant growth, but a high inflow of phosphorus into the water can increase eutrophication²⁷. Total phosphate available in a given water source are due to sewage, detergents and fertilizers which leads to growth of microorganism. To accelerate the plant growth, farmers use maximum amount of phosphate fertilizer for the agriculture land which results in the contamination of water bodies through run off and affects aquatic life²⁸⁻²⁹. Spatial analysis of total phosphate (Fig. 7) content of water varies from 0.1 mg/L from 2.5 mg/L and its average range is 0.47 mg/L.

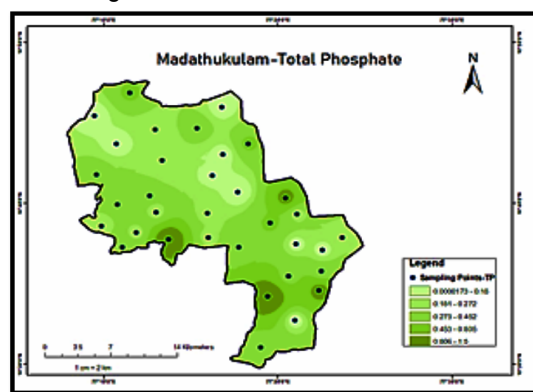


Fig. 7. Spatial distribution of TP

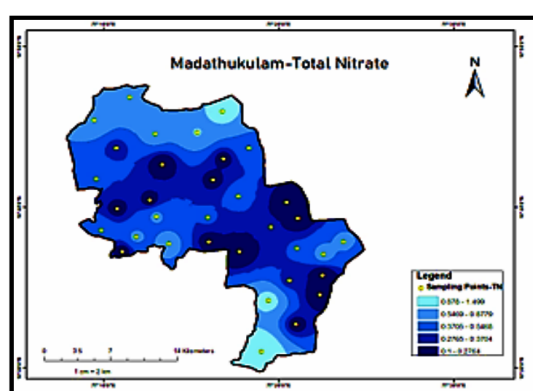


Fig. 8. Spatial distribution of TN

Total dissolved solids (TDS) in water result from the presence of dissolved inorganic salts as well as organic matter in water. The major ions sodium, potassium, chloride, carbonate are responsible for TDS values³⁴. Spatial analysis map (Fig. 10) of

(Fig.11) electrical conductivity ranged from 0.07 mS to 3.37 mS (avg. 1.032 mS), where all the samples are within the permissible limit, as per WHO⁷, the permissible limit for EC is 300 mS.

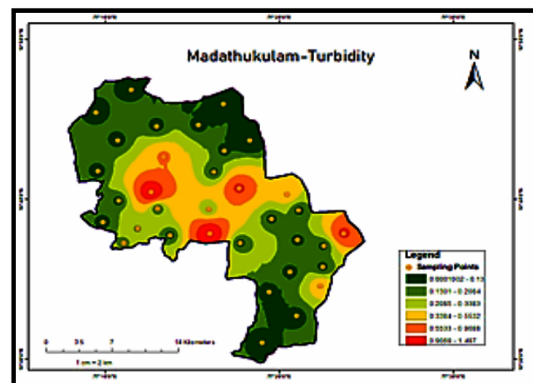


Fig. 9. Spatial distribution of turbidity

Table 1: Analysis of Some Physico-chemical parameters in Madathukulam Taluk

Sampling Points	Source	DO%	FC MPN/100 pH	BOD mg/L	Temp°C	TP mg/L	TN mg/L	TUR NTU	TDS mg/L	Con mS	T.H mg/L	Cl- mg/L	F- mg/L	Na+ mg/L	K+ mg/L	
S ₁	BW	73.6	3	7.23	0.5	25.4	0.1	0.3	0.1	382.4	0.8	344.8	255.2	0	69	6
S ₂	BW	77.9	2	6.2	0.9	24.2	0.2	0.6	0.2	252.1	0.5	215.5	191.4	0	48	8
S ₃	OW	56.2	6.5	6.4	2.5	25.6	2.5	3.6	1.5	1258.9	2	336.2	684.1	0	69	7
S ₄	BW	65.9	3	6.9	3.6	25.6	0.1	0.5	0.2	479	1.07	346.2	684.1	0	47	2
S ₅	BW	74.5	4	7.4	0.7	25.3	0.3	0.2	0.1	1300	2.88	615.4	748.2	0	36	0
S ₆	BW	89.6	5	6.2	0.4	24.6	0.4	0.4	0.1	742	0.69	900	159.2	0	97	5
S ₇	BW	81.2	4	6.8	0.6	26.3	0.3	0.1	0.1	443	1.05	326.9	350.9	0	35	3
S ₈	R	56.8	110	6.1	2.8	28.4	0.2	0.6	1	114.1	0.25	173.1	148.7	0	17	5
S ₉	BW	68.4	4	6.7	0.4	24.6	0.1	0.7	0.1	1570.6	3.37	461.5	798.7	0	26	2
S ₁₀	OW	63.9	96	6.2	2.7	23.4	0.2	0.1	0.6	34	0.07	115.4	241.1	0	13	0
S ₁₁	BW	89.5	5	6.4	0.5	24.2	0.1	0.2	0.1	401.2	0.99	576.9	258.8	0	19	1
S ₁₂	BW	78.3	4	7.1	1.3	24.6	0.3	0.2	0.1	495	1.17	461.5	357.7	0	46	2
S ₁₃	BW	75.4	3	7.2	0.8	26.9	0.5	0.8	0.1	317	0.75	346.2	209.1	0	31	1
S ₁₄	BW	56.3	5	6.5	2.5	25.9	0.2	0.4	0.2	183	0.42	365.4	184.3	0	15	1
S ₁₅	BW	65.3	4	6.3	1.5	25.1	0.4	0.9	0.1	651	1.63	750	492.7	0	36	2
S ₁₆	P	42.3	120	7.3	2.6	27.9	1	0.2	0.9	1350.2	3.06	1173.1	699.7	0	39	2
S ₁₇	BW	67.3	6	6.3	2.2	25.2	0.5	0.3	0.1	170.1	0.5	146.7	297.8	0	87	12
S ₁₈	BW	56.3	4	7.1	2.6	26.3	0.2	0.9	0.1	170.1	0.5	146.7	297.8	0	35	9
S ₁₉	BW	63.7	3	7.2	1.8	24.3	0.4	0.2	0.2	459	1.04	365.4	492.7	0	52	3
S ₂₀	BW	56.4	2	6.9	1.9	26.3	1.5	0.3	0.1	46.2	0.1	173.1	187.9	0	23	2
S ₂₁	BW	72.3	2	6.8	1.5	24.6	0.2	0.5	0.1	450.2	0.23	900	158.9	0.5	56	6
S ₂₂	BW	89.6	3	6.7	0.5	25.9	0.3	1.5	0.1	75.2	1.5	566.6	253.6	1	69	9
S ₂₃	BW	73.8	4	7.1	1.5	24.9	0.1	1.1	0.1	123.4	2.3	1033	123.4	0	45	5
S ₂₄	L	45.3	110	6.5	2.9	28.9	1.5	2.3	1.5	456	1.05	600	231	0	64	2
S ₂₅	OW	48.9	11	6.2	2.4	25.9	0.5	1.2	0.5	125.8	1.2	433.3	214.3	0	89	2
S ₂₆	BW	73.2	5	6.3	2.3	24.6	1.5	0.7	0.1	354	1.03	566.6	210.2	0	59	5
S ₂₇	OW	54.1	100	6.1	2.6	27.9	1	1.5	0.5	47	0.23	533.3	95.2	0	94	9
S ₂₈	BW	69.4	4	7.2	1.8	24.2	0.2	0.6	0.1	251	0.58	600	89.5	0	56	7
S ₂₉	OW	64.3	120	6.4	2.9	28.2	0.3	1.2	1.5	345	0.68	633.3	78.4	0	45	4
S ₃₀	BW	65.8	5	6.5	1.3	24.5	0.3	0.1	0.1	41	0.23	1366	98.4	0	98	3
S ₃₁	BW	56.3	4	6.7	1.5	25.6	0.1	0.4	0.1	256	0.24	800	69.8	0	35	7
S ₃₂	OW	49.8	7.9	6.8	2.3	26.1	0.1	1.3	0.1	145	0.54	1600	86.3	0	56	4
S ₃₃	OW	36.9	9.8	7.1	2.5	25.3	0.2	1.4	0.1	165	0.68	433.3	74.2	0	84	2
S ₃₄	OW	49.5	8.6	6.7	2.6	24.6	0.4	1.5	0.1	84	1.24	833.3	145.6	0	69	4
S ₃₅	R	53.2	123	6.3	3.1	24.7	0.1	1.9	0.1	95	1.45	1366	123.4	0	59	6
WHO(2017) Standard			10	6.5-8.5	25-30		45	<5	<500	600	300	1000	1.5	200	12	
Value			Not detected													
BIS (2012)				6.5-8.5	25-30			<5	<500	600		1000	1.5			12

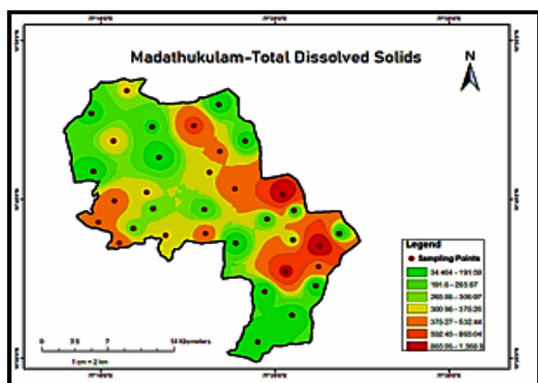


Fig. 10. Spatial distribution of TDS

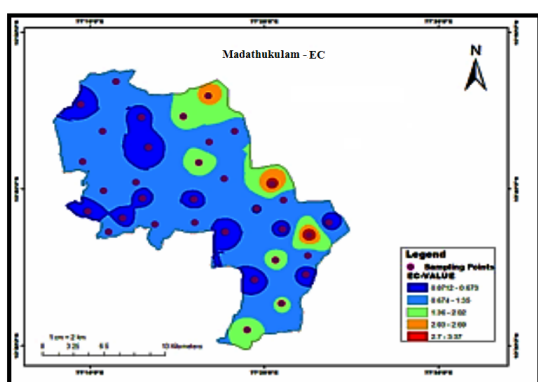


Fig. 11. Spatial distribution of EC

Total Hardness of water is a degree of dissolved Ca^{2+} and Mg^{2+} content expressed as CaCO_3 and it is the capacity of water to cause the precipitation of insoluble calcium and magnesium salts of the upper fatty acids of soapy solutions³⁷. Magnesium is often combined with calcium in all kinds of water. According to WHO, the permissible limit of total hardness is 200 mg/L and maximum limit is 600 mg/L. In the present study total hardness of the analysed water sample ranged from 115.4 mg/L at S_{10} to 1600 mg/L at S_{32} with a mean value of 588 mg/L (Fig.12) and 11 sampling points (S_5 , S_6 , S_{15} , S_{16} , S_{21} , S_{23} , S_{29} , S_{31} , S_{32} , S_{34} , and S_{35}) have a hardness exceeding 600 mg/L. The high levels of total hardness are found in all stations except S_8 , S_{10} , S_{17} , S_{18} and S_{20} and 57% of water samples have total hardness above the permissible limit recommended by WHO⁷.

Chloride is one of the major inorganic anion present in water. The concentration of chloride can vary due to geochemical conditions, industrial waste, sewage disposal, leaching of salt residues into the soil. High concentration of chloride produces peculiar

salty taste in drinking water³⁸. The concentration of chloride and fluoride ranged from 69.8 mg/L to 798.7 mg/L (mean value of 276 mg/L) and 0 mg/L to 1 mg/L (mean value of 0.04 mg/L) respectively. According to WHO, the permissible limit for chloride and fluoride are 250 mg/L and 1.0 mg/L⁷. Spatial analysis of chloride (Fig. 13) reveals that 60% of the samples have <250 mg/L and fluoride (Fig.14) content are lower than the WHO limit. Sodium and potassium ions are principal ion in body fluids, at low concentration it's intake in form of a combined food or water sources is important. But increased intake of sodium in drinking water leads people to hypertension, heart disease or kidney problem³⁹. The observed concentration of sodium and potassium ion varies from 13 mg/L to 98 mg/L and 0 mg/L to 12 mg/L with an average value of 51.94 mg/L and 4.23 mg/L respectively. The permissible limit of sodium is 200 mg/L and potassium is 12 mg/L respectively. Spatial analysis of sodium (Fig. 15) and potassium (Fig. 16) ion for water samples reveals that all the samples are within the permissible limit of WHO⁷.

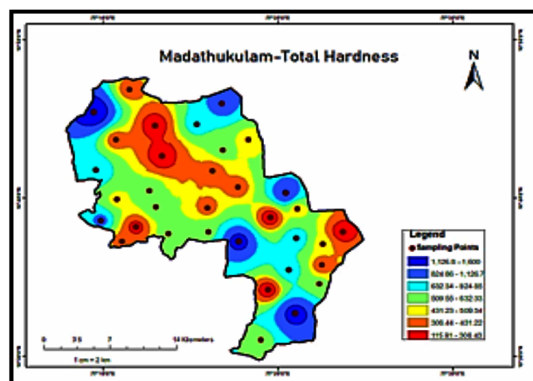


Fig. 12. Spatial distribution of TH

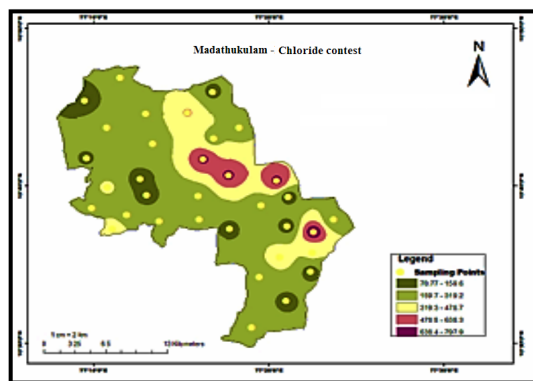


Fig. 13: Spatial distribution of chloride

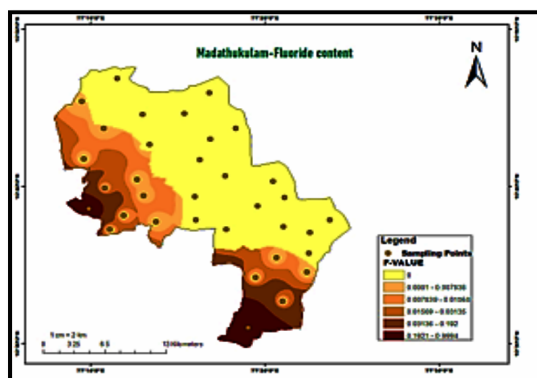


Fig. 14. Spatial distribution of fluoride

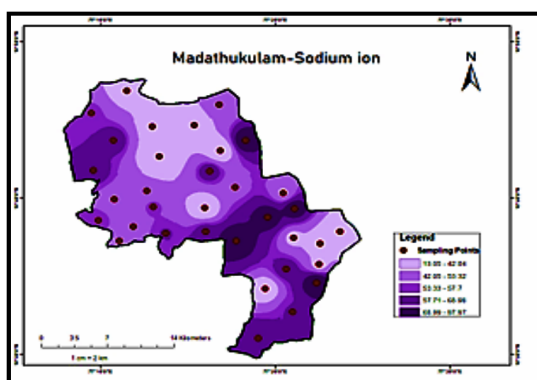


Fig. 15. Spatial distribution of sodium

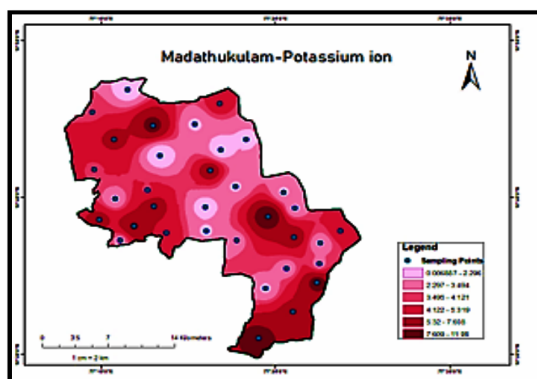


Fig. 16. Spatial distribution of Potassium ion

Water Quality Index

Water quality index provides useful information on water quality by monitoring water quality parameters and it is the effective way to communicate the overall quality of the water. According to NSF-WQI water was classified into five types, if the WQI between 90-100 means excellent quality, 70-89 means good quality, 50-69 means medium quality, 25-49 means bad quality and 0-24 refers to very bad quality of water. In the present study, the calculated WQI ranges from 52.5 to 82.5 and the result, reveals that different sampling stations

have different water quality. 63% of water sampling sites have good water quality and the remaining 37% fall into the medium quality category. The higher WQI (82.5) was recorded at S_{22} and the lower WQI (52.5) was observed in S_{24} , this sample was collected from lake, the value indicate that the water quality was poor and shows higher level of pollution which are directly discharged into lake. Fig.17 illustrates the spatial distribution WQI map. The study highlights that the single value of WQI has enough and higher sensitivity to classify the water quality rather than long list of value with a large number of parameters. WQI methods will help developers in monitoring and assessment of the quality of water in the study area. 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.18 pictured the close relationship between the NSF and the Modified NSF water quality index values.

Table 2: Calculated NSF-WQI and MNSF-WQI values

Sampling Points	Source	NSF WQI	MNSF-WQI
S_1	BW	80.35	80.65
S_2	BW	79.03	77.76
S_3	OW	57.36	58.14
S_4	BW	72.64	76.97
S_5	BW	76.41	78.33
S_6	BW	74.05	75.22
S_7	BW	77.87	78.34
S_8	R	63.06	60
S_9	BW	74.95	76.37
S_{10}	OW	66.42	63.88
S_{11}	BW	79.25	79.59
S_{12}	BW	77.15	78.92
S_{13}	BW	77.19	76.12
S_{14}	BW	70.75	69.95
S_{15}	BW	68.97	69.79
S_{16}	P	54.29	53.96
S_{17}	BW	70.39	68.54
S_{18}	BW	72.89	72.73
S_{19}	BW	72.73	73.77
S_{20}	BW	69.92	66.04
S_{21}	BW	78.07	79.63
S_{22}	BW	82.52	80.15
S_{23}	BW	80.91	79.67
S_{24}	L	52.5	50.23
S_{25}	OW	64.93	61.6
S_{26}	BW	67.27	66.96
S_{27}	OW	57.99	52.84
S_{28}	BW	78	78.11
S_{29}	OW	63.44	62.98
S_{30}	BW	78.12	75.34
S_{31}	BW	73.82	71.94
S_{32}	OW	72.39	71.09
S_{33}	OW	68.85	67.24
S_{34}	OW	69.62	67.64
S_{35}	R	73.26	70.89

(BW–Bore well, OW–Open well, L – Lake, R – River, P –Pond)

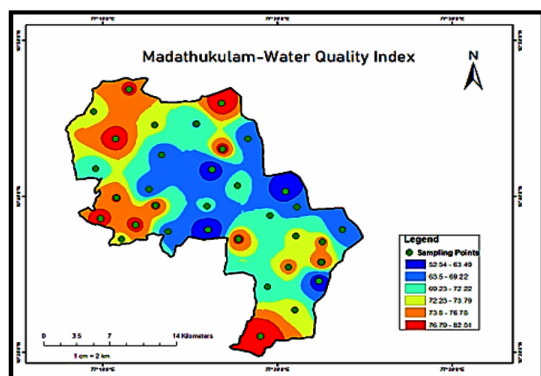


Fig. 17. Spatial distribution of WQI

Comparative WQI of NSF-WQI & MNSF-WQI

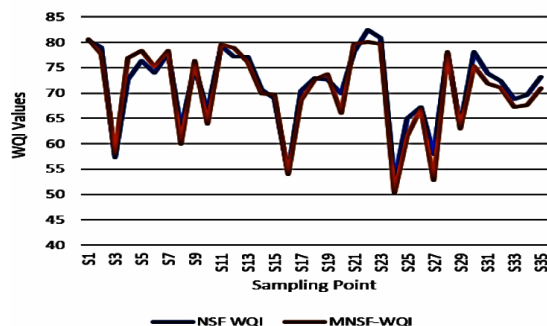


Fig. 18. Comparison of the WQI values of NSF and MNSF

Correlation analysis

In order to observe the relationships between the physico-chemical parameters calculated, a correlation analysis was performed.

A correlation coefficient (r) closer to +1 or -1 shows a perfect linear relationship between the two parameters and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values for r indicate a reciprocal relationship. Correlation coefficient (r) between any two parameters, x and y , among the selected water quality parameters of Madathukulam Taluk is shown in Table 3. The degree of line association between any two parameters as measured by simple correlation coefficient (r) is represented in 17*17 matrix. From the Table 3, it is observed that faecal coliform showed positive correlation with temperature ($r=0.67$), Turbidity ($r=0.8$). TDS is significantly in a positive correlation between conductance (0.76) and Cl (0.78), because a total dissolved solid depends on ions. There is a strong positive correlation between conductance and chloride (0.74), this is reliable with the fact that conductivity increases as the concentration of ion increases. Total hardness is in strong positive correlation with calcium hardness ($r=0.75$). Calcium hardness showed a significant positive correlation with magnesium hardness. DO, BOD, temperature, total phosphorous, total nitrate and chloride are negatively correlated. It can be resolved that the correlation analysis of the water quality parameter is highly important in the study of water bodies.

Table 3: Correlation coefficient for different water quality parameters

Parameters	DO	FC	pH	BOD	Temp.	TP	TN	TUR	TDS	Con	T.H	Cl	F	Na ⁺	K ⁺
DO	1														
FC	-0.3758	1													
pH	-0.215	0.0589	1												
BOD	-0.8047*	0.5752*	0.0082	1											
Temp.	-0.3962	0.6664*	0.2518	0.4029	1										
TP	-0.1591	0.1676	0.0561	0.2791	0.2056	1									
TN	0.181	-0.3074	-0.034	-0.1568	-0.0051	0.1571	1								
TUR	-0.2769	0.8000*	0.0263	0.4338	0.6370*	-0.0778	-0.2285	1							
TDS	0.1351	0.0623	0.1172	-0.3541	0.0139	0.0032	-0.1263	0.0105	1						
Con	0.1143	-0.0457	0.1223	-0.3235	-0.0197	-0.0513	0.0836	-0.1152	0.7582*	1					
T.H	-0.1825	-0.0377	0.023	0.04343	-0.0543	-0.0854	-0.0006	-0.1235	0.0886	0.205	1				
Cl	0.1989	-0.0473	0.1649	-0.415	-0.0385	-0.044	-0.0707	0.0009	0.7777*	0.7477*	-0.1729	1			
F	0.3108	-0.1115	-0.0275	-0.226	-0.0234	-0.0593	0.4939	-0.1064	-0.1084	0.0127	0.0567	-0.0607	1		
Na ⁺	-0.0468	-0.1237	-0.031	-0.003	-0.0447	0.0876	-0.1871	-0.1395	-0.2167	-0.107	0.2847	-0.2714	0.1243	1	
K ⁺	0.1577	-0.0938	0.0044	0.004	0.0215	-0.0043	0.1899	-0.147	-0.3499	-0.2394	-0.051	-0.322	0.3029	0.4321	1

CONCLUSION

The present study reveals that the use of WQI and GIS methods could provide valuable

information for assessment of water quality. The GIS is considered as an effective tool because with the GIS software, various maps showing the spatial distribution of water quality parameters have

been prepared and analysed. These techniques have successfully demonstrated its capability of ground and surface water quality mapping of Madathukulam Taluk of Tiruppur district. A total of 35 water samples (23 from bore well, 8 from open well, 2 from river, 1 from lake and 1 from pond) were collected and investigated for various physico-chemical characteristics. The physicochemical parameters pH, TDS, TH are above the permissible limit referring to WHO (2017). On comparing the results of DO, FC, temperature of ground water and surface water, samples from surface water have low DO value and high FC and temperature. From this result it reveals that these values are triggered by the pollution due to paper, textile and dyeing industries in Madathukulam Taluk. GIS based Water Quality Index shows that 63% of the area has recorded with

good quality water, while the remaining 37% are of medium quality of water. The result of the present study revealed that the chemistry of water bodies of the Madathukulam Taluk needs proper sanitation and proper plans for managing and protecting the surface water resources.

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Conflict of interest

The authors declare that they have no conflict of interest.

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